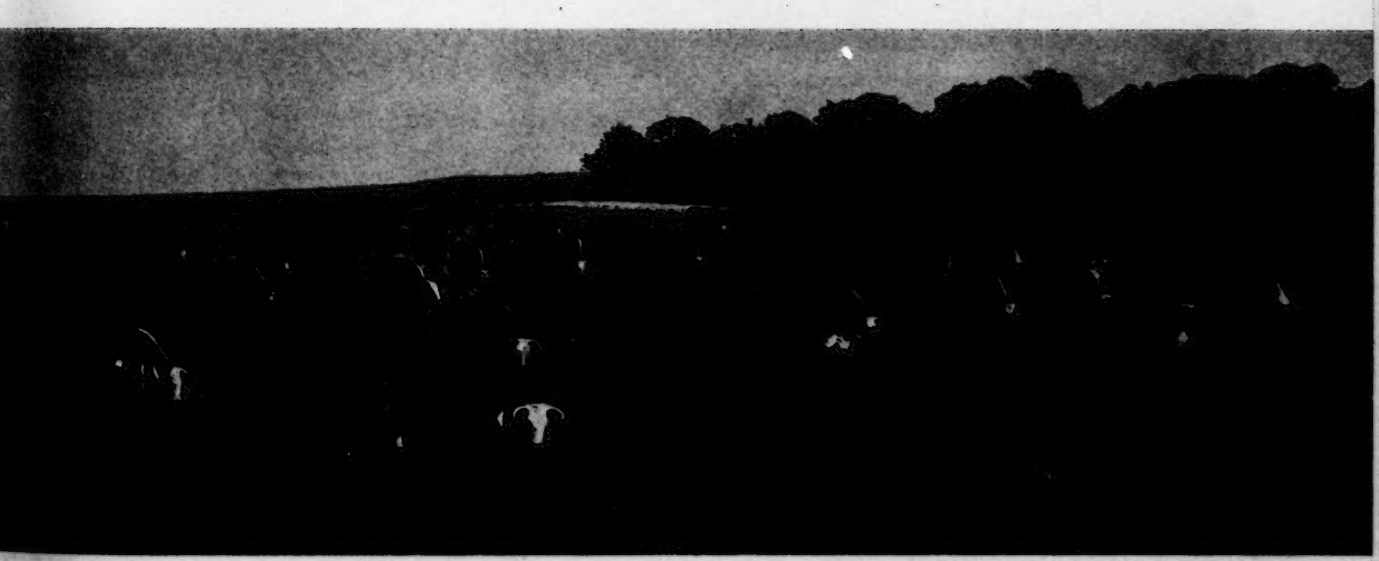
VOLUME 5, No. 4, PART 1. OCTOBER 1950

Bluestem on the Longhorn Trails by B. W. Allred

Effect of Land Use Practices on Ground Water by H. W. Lull and E. N. Munns

Soil Fertility: A Major Factor in Conservation by Emil Truog



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* * * *

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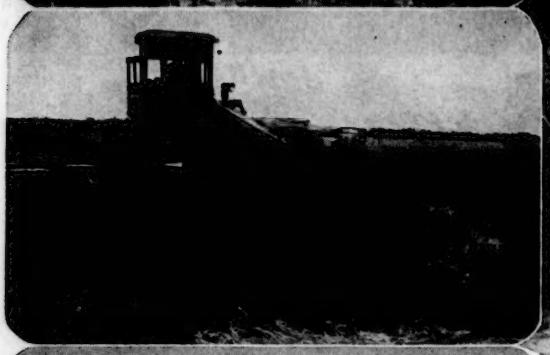

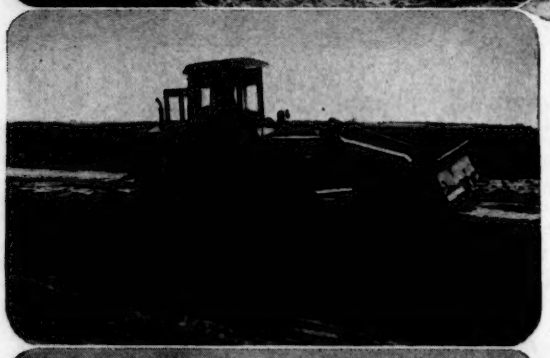

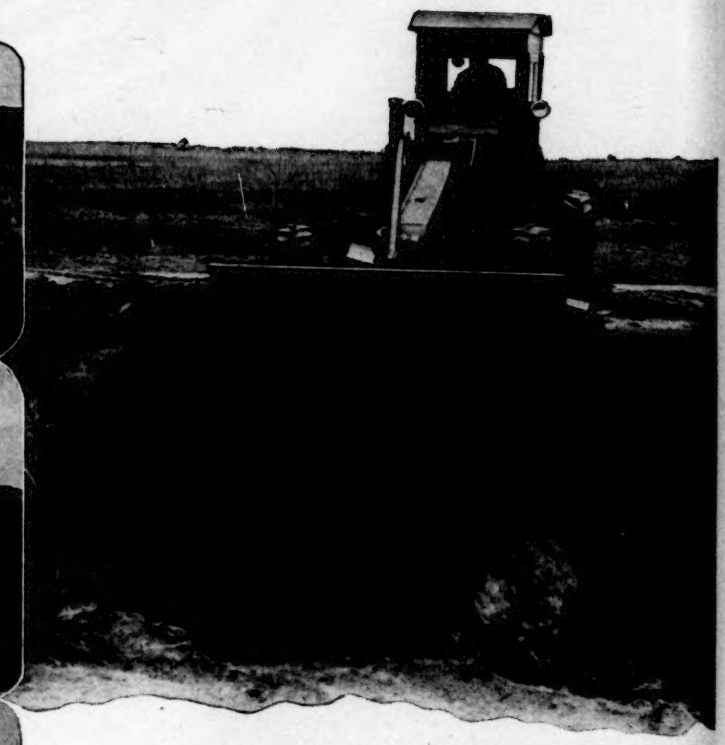

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VOLUME 5
NUMBER 4
PART 1

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Contents for October, 1950

From the Editor 150

Bluestem on the Longhorn Trails 151
B. W. ALLRED

A System of Soil Profile Characterization 158
R. M. SMITH AND GEORGE SAMUELS

Weeds—Water Robbers 165
ROBERT B. BALCOM

Effect of Land Use Practices on Ground Water 169
H. W. LULL AND E. N. MUNNS

Pictorial Section 171

Soil Fertility: A Major Factor in Conservation 180
EMIL TRUOG

Recent Research Reviews 186
JAMES H. STALLINGS

Field Notes and Comments 188

Book Reviews 192

Index—Volume 5, 1950 199

COVER. This bluestem range near Walnut Springs, Texas, has been grazed by cattle for 75 years. It has been used correctly and still is in excellent condition. Range management in all its aspects is basic to a profitable livestock industry. *Photo by Hermann Postlethwaite, Soil Conservation Service.*

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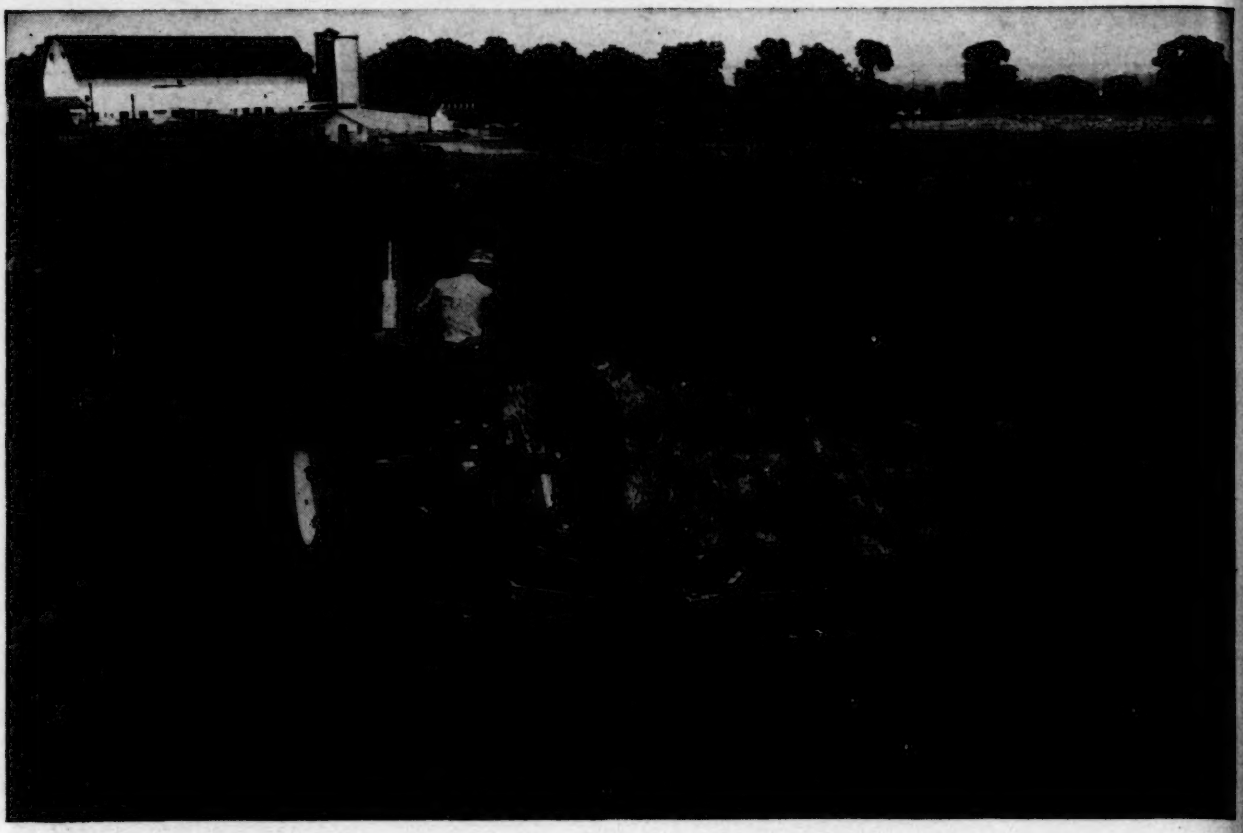

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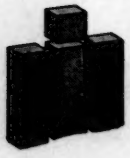

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From the Editor

"Splash Erosion in Pictures" by W. D. Ellison was judged by members of the Soil Conservation Society of America as the most outstanding article to appear in the last four issues of the JOURNAL. Firman E. Bear's article entitled "The Minor Element Situation" placed second; "Ideals of a Professional Soil Conservationist" by Henry W. Schmitz, third; "The Value of Crop Rotations for Soil and Water Conservation" by R. E. Uhland, fourth and "Conservation as a Movement" by Carl C. Taylor, fifth.

The article by Mr. Ellison, following publication in the JOURNAL, brought forth many inquiries from field workers, industrial concerns and professional interests requesting additional information about the photographs or permission to reprint the article. Plates from which the photographs were made were loaned to a leading technical journal for reproduction.

The Farmer's Book Club, a Division of the Devin-Adair Company, New York, under the able leadership of Devin A. Garrity is now well along. It was launched a few months ago and already lists many members of the Soil Conservation Society of America and others throughout the land. Mr. Garrity's organization is in an excellent position to contribute much to the conservation movement through the proper selection of good books. "Our purpose," pointed out Mr. Garrity in a letter, "will be to urge sound conservation and to avoid books which in any way tend to urge a mining of the soil." All books listed in the newsletter issued by the Club are practical in every respect and should be owned by farmers or persons working with farmers. The Farmer's Book Club represents another tool that can do much to further extend conservation and good agriculture.

Part 2 of this issue of the JOURNAL is in the form of an official membership directory. It contains more than 4000 names—all members of the Society.

The Centro Nacional De Investigaciones, Chinchina, Colombia, South America, recently published a handbook entitled "Defendamos Nuestros Suelos." *It is written in Spanish and contains many excellent photographs showing erosion and land use conditions in Colombia; also conservation practices that are being installed on the land. The publication is pocket size and most attractive.*

An annual award for the best writings in the general field of soil and water conservation was recently proposed by a committee representing the Society. It would consider a series of awards covering the best book, the best magazine article, the best newspaper article, the best editorial, the best advertisement, the best bulletin—of the year. This excellent proposal possesses considerable merit and would contribute much to the conservation movement.

Early during the year, the West Virginia Chapter of the Soil Conservation Society of America prepared and mailed a questionnaire to the membership concerning articles and items appearing in the JOURNAL OF SOIL AND WATER CONSERVATION. It also included a number of questions pertaining to professional improvement.

Ninety-three members filled in the questionnaire. Their interests varied according to positions held. In summation, about one-third stated that they preferred articles of a policy or philosophical nature; another third wanted technical articles and those remaining favored articles based on experimental or field work. This indicates that feature articles appearing in the JOURNAL are in good balance. "Recent Research Reviews" rated very high, as did the Pictorial section. More than 90 percent of the members expressed the need for a section in the JOURNAL devoted to techniques, observations or experimental work conducted by field men.

How many readers of the JOURNAL in other sections of the country concur with these results? A general cross section of views and suggestions would be helpful to the Editorial Board in putting out the kind of publication desired by its readers. Why not mail a letter to the Editor today expressing your views?

E. L. Sauer, Urbana, Illinois, writes: "I always enjoy the editorial page in the JOURNAL. Quite frequently we hear that people are not interested in economic information and economic data, but when I learned from your editorial that Deere and Company has distributed 65,000 copies of an advertisement *"An Easy Lesson in Hard Facts"* it gave me a boost. This advertisement is based on our economic research data pointing out the dollars-and-cents benefits from soil and water conservation and erosion control." *It pays to advertise. Perhaps others could do well to work with advertisers to disseminate research data.*

Bluestem on the Longhorn Trails

B. W. ALLRED

This is the story of the Bluestem Belt. It may also be said to be the history of man in search of food. Mr. Allred vividly describes the early condition of the range and how millions of acres were badly depleted because of misuse. He also describes with clarity the principal characteristics and limitations of each of the six major companion grasses that are common to this area. In addition to building the range for an expanding livestock industry, all of the grasses discussed are good conservation plants when grazed correctly. This, too, is all important to the Bluestem Belt.

THE BLUESTEM BELT, the most productive native grassland of the primeval American continent, lay in the area extending from Lake Winnipeg, Canada, to the Gulf of Mexico. It was bounded eastward by the hardwood forest and westward by the Great Plains. Hundreds of plants grew in the prairie but only a few produced the bulk of the total forage. Mid and tall grasses were the most important.

This rich area has been changed more than any other grassland as a result of settlement, farming, grazing and burning. However, millions of acres remain unplowed and a few remnants of the former prairies still are in excellent condition. These provide a natural source of seed with which to plant and reclaim large areas of abandoned farm lands that need to be seeded.

Seed of these good grasses has been planted on thousands of acres in soil conservation districts but the need still far exceeds the amount available. In the fall of 1948, soil conservation district supervisors of Oklahoma and Texas and the U. S. Soil Conservation Service harvested over three and one-half million pounds of prairie grass seed in northeastern Oklahoma. This was the largest native grass seed crop ever taken by man. Seed sold for twenty to thirty-five cents per pound, depending upon purity.

Early History of the Bluestem Belt

Cabeza de Vaca and the Negro, Esteben, were the first Europeans known to have entered the Bluestem Belt. They were the only survivors of a Spanish exploratory fleet shipwrecked near the mouth of the Sabine River in 1528. They wandered for many months over the bluestem prairies of South Texas as captives and slaves of various Indian tribes.

Finally, after several years of peril and hardships they ran into some Spaniards near Culican, Mexico. From central Texas they traveled westward to near the present site of Presidio, Texas, on the Rio Grande and from there struck southwest. So far as is known, they never reached New Mexico or Arizona. The extravagant tales told about the seven golden cities of Cibola, by Esteben, excited the gold-seeking Spaniards. After hearing these tales Coronado organized his famous expedition to find the seven golden cities of Cibola.

Coronado and the members of his army of misguided fortune hunters brought the first horses, cattle and sheep into the Bluestem Belt. They broke into it along the Canadian River in Texas in 1541. The livestock were brought to provide food for Coronado and his men. It is doubtful if any animals survived in the United States, although cattle herds originated from individuals dropped by his expedition near Sinloa, Mexico.

Spaniards introduced the first cattle into Mexico in 1521. The foundation Texas cattle, 200 head, were trailed from Mexico across the southern end of the Bluestream Belt and delivered to a Spanish Mission on the Texas and Louisiana line in 1690.

Spanish cattle multiplied and ran wild along the Gulf Coast. These old "Corrientes" mothered the Texas Longhorn bred in the tall bluestem grasses of the prairies between the Trinity and the Nueces rivers.

There was no outlet for the surplus cattle that loaded the ranges during the Civil War. Cattle were thin and the bluestem was grubbed to the nub.

Then the relief lines, the cattle trails to Kansas railheads and Montana and Dakota miners, pioneer ranchers Indian Agencies opened up.

The Eastern trail ran north and south through the Bluestem Belt. The part extending through the Indian Territory, now Oklahoma, was called the Chisholm trail. The Eastern trail began near Kingsville, Texas, and joined the Chisholm trail at Red River crossing, north of Bowie, Texas. Cattle off the Texas bluestem ranges drained in from feeder trails below Red River and followed the Chisholm trail to Kansas, where some were shipped eastward by rail. Many were dispersed

B. W. Allred, a frequent contributor to the JOURNAL, is Regional Range Conservationist for the Soil Conservation Service with headquarters in Fort Worth, Texas. He is the author of numerous articles and papers featuring grasses and their management on the range. Mr. Allred also compiled and edited a book in cooperation with Edith S. Clements entitled *Dynamics of Vegetation* written by Frederic E. Clements. He has also written a new book entitled "Practical Grassland Management," published by H. M. Phillips, Editor, *Sheep and Goat Raiser*, San Angelo, Texas.

through forking trails that led them to their northward destination.

The Western trail began at Brownsville, Texas, and veered northwest to the famous Doan's Crossing on the Red River northwest of Vernon, Texas. From there the trail led north to Dodge City, Kansas, Ogallala, Nebraska, and either feathered out eastward along the Black Hills into North Dakota or carried on west of the Black Hills across the Bell Fourche, Powder, Yellowstone, and the Missouri rivers to the Indian Agencies along the Milk River on the Montana High Line. Even the cattle on the Western trail never ran out of bluestem, for the drainages, north slopes and sandy areas all the way to the Milk River produced bluestem which alternated with the mid and short grasses of the Mixed Prairie on the drier sites.

Many of the herds were delivered to railheads and Indian Agencies as beeves; also northern ranchmen preferred to buy herds that were fat enough to winter well; consequently the trail drivers spread the herds through the best grass in order to fatten them on the way. As much as possible the trail bosses kept their cattle away from heavily grazed sections except as they were forced to for safe crossings on rivers or for water. At places the Chisholm and Western trails were 50 miles wide.

Trail herds didn't kill the bluestems completely, as many have claimed. Today bluestem range alternates with cotton patches at Doan's Crossing on the Red River.

A large monument on a ranch east of Addington, Oklahoma, marks the former location of a popular trail herd bedground. Cattle trailing up from the Red River Crossing were bedded on Monument Hill where the cow hands could see a wide country within a half-day's drive from all directions. Bluestems still are the main grasses on this ranch. East of the Monument a long gully marks the old chuck wagon road. Now the gully is healing with bluestems.

Open range Longhorn cattle developed into the wildest cud-chewers in America. It took a tough breed of men to manage them. While the Longhorn and the cowboys that snaked cattle out of the Texas brush country and herded them up the trail are gone, but the memories of both are here to stay as part of our colorful Americana. Only ten million Longhorns went up the trails from Texas between 1866 and 1890 and they brought ranchmen less than $10 to $25 a head at home.

The annual income from music, literature, art and entertainment which deals with the subject of cowboys, trail drivers and Longhorns must make the yearly income for trail driving look like small change.

The Longhorns are gone and conditions that perpetuated the trail driving cowboy went by in 1896 when fences, farming and railroads blocked the trail in thousands of places. But a lot of the bluestem grasses remain and they are becoming more prominent as good grass management sponsored by Soil Conservation District Cooperators helps them increase.

Grasses of the Bluestem Belt

When you think of bluestem you have to think of the companion grasses too. Little bluestem is most important, but it and big bluestem, sand bluestem, Indiangrass, switchgrass and sideoats grama are the big six of the Bluestem Belt and each has special values and specific limitations in the area.

Little Bluestem. Little bluestem (*Andropogon scoparius*) is one of the most broadly distributed perennial grasses in the United States. It is adapted to widely different soils and slopes, but produces most on sites where soil fertility, soil moisture and drainage are most favorable. It grows native in all states of the union except California, Washington, Oregon and Nevada. There are 32 different but closely related bluestem grasses in the United States. Many species of bluestem are found in foreign countries such as Mexico, the Orinoco River basin in South America, South Africa and Australia.

While the bluestem is a wide-ranging grass, it originally grew most abundantly in the great midlands of North America, extending from Lake Winnipeg, Canada, to Victoria, Texas, on the Gulf of Mexico. The main little bluestem belt extended from the 100th meridian on the west to eastern Minnesota, eastern Indiana, northwestern Missouri, eastern Oklahoma, south to Port Arthur, Texas.

Extensive plowing and grazing have reduced the plant to a minor fraction of its former range. It has suffered less from the plow and over-grazing from the Flint Hills of Kansas to the Gulf of Mexico. It has invaded extensively into the cut-over lands of Arkansas, Louisiana and East Texas since the forests have been lumbered and burned.

Little bluestem is a warm season plant, completing its major growth during the frost-free period. Its water requirements are relatively high. While it thrives best in the sub-humid midland prairies, it survives in the semi-arid west on sites where moisture situations are unusually favorable, such as sand hills, north hillsides, and drainages.

The most widely used common name for the grass is little bluestem but it has many others of local significance. It and several other bluestem grasses are called sagegrass in the South and Southwest.

Little bluestem increases its crown spread from tillering crown buds and short rootstocks. Abundant tillering takes place early in the growing season. The finely branched fibrous root system occupies the soil completely at considerable depth. The roots spread hori-

Figure 1. Fat Herefords on excellent bluestem range near Henrietta, Texas. Under the conservation grazing program initiated the bluestems have increased from seed and root extensions while the threeawns and poor weeds have thinned out. One year the owners combined 1500 pounds of seed from 20 acres.

zontally and grow shallow in sandy soils and those with an impervious hard pan close to the surface. However, they grow straight down to maximum depths in pervious clay and loamy soil.

It is an extremely leafy and erect plant, growing 18 inches to 5 feet high. The leaves and stems remain blue or green until maturity, when they turn a characteristic rusty-purple.

Little bluestem still makes up an important part of the range forage and native hay from the Flint Hills of Kansas to the Gulf of Mexico. It provides nutritious grazing during the frost-free period in the spring until it matures in the fall, and has been used for hay since the first days of settlement. Protein and mineral supplements often need to be added to the ration, however, when the plant is grazed after maturity.

It is customary for south Texas stockmen to ship cattle from Texas bluestem and other ranges to fatten on little bluestem ranges in the Kansas Flint Hills and Oklahoma Osage Hills. About a half million south Texas cattle were grass-fattened there in the summer of 1949.

Many areas that were formerly eroded have been seeded to this grass and now have a thrifty protective cover of bluestem pasture or hay meadow. It has proved satisfactory in developing vegetated waterways in drainages to reduce gullying and soil losses. Some farmers on soil conservation districts have used it successfully as a perennial grass buffer to absorb the short rows and odd pieces of their contour farming operations. These bluestem buffer strips give valuable soil protection and also provide a good hay crop.

There is considerable variation in yield, leafiness, feed value and season of development as there is in other grasses. The United States Department of Agriculture and State Experiment Station plant breeders have developed some strains of little bluestem that are uniformly high in yield, quality and erosion control values.

Sideoats Grama. Sideoats grama (*Bouteloua curtipendula*) is the aristocrat and most robust of the grama grasses. It is a perennial warm season plant that stays dormant until temperatures remain constantly above 30 degrees Fahrenheit. Seed stalks reach 15 to 30 inches in height under range conditions.

It reproduces from seed and from vigorous creeping, scaly rootstocks; has flat leaf blades with glandular hairy margins; frequently reddish in color at maturity. It grows erectly and forms an open sod. The seeds are arranged uniformly down one side of a stiff stem. From this distinctive feature came the name "sideoats" grama.

Sideoats grama grows from Canada to Argentina. It is most common in the United States east of the Rocky Mountains, particularly in the region east of the 100th Meridian to the forests of central United States and the Southwest.

It is one of the climax plants of the sub-humid prairies where it grows in harmonious association with the bluestem grasses. It has a higher water requirement than the other gramas and, when found west of the 100th Meridian, it usually grows where water relations are best.

Sideoats grama is a warm season mid grass and yields high quality forage when green. It is usually ready to graze by April 1 on the Gulf Coast and about June 1 in North Dakota. When moisture is ample and grazing moderate, green foliage continues to grow until frost. It has fibrous roots that tap deep soil moisture reserves

when available soil water in the surface soil is exhausted.

Fudge and Fraps of the Texas Agricultural Experiment Station found that sideoats grama in the young stage ran about 10 per cent in protein but when mature, it ran about 4½ per cent in protein. It provides good winter roughage, but needs to be supplemented with protein. Yields of hay and grazing from this grass lie intermediate between that from little bluestem and buffalograss and blue grama.

Before domestic livestock altered the original conditions of the subhumid prairies, sideoats grama and associated climax grasses that covered the prairies provided a solid defense against soil erosion. These same plants are still doing an effective job of soil erosion control on ranges where prudent grazing has allowed them to continue to grow. Forty to fifty per cent of the annual growth of sideoats grama can be harvested by animals each year and enough will be left to promote plant growth and provide leaves and stems in the form of litter to break the fall of beating rain and prevent water erosion and runoff.

This is one of the many native plants that the Soil Conservation Service has domesticated for soil conservation purposes. In 1944, over 127,000 pounds worth nearly $50,000.00 were harvested by Soil Conservation Service nurseries, commercial seedsmen and farmers. It has been widely used in the plains and prairies in reclaiming worn-out and eroding farm and depleted range land. It grows well on a great variety of soils and has been established artificially on both fine and coarse-textured soils. It should not be planted on coarse dune sands or extremely alkaline areas. Both local and regional variations provide breeders with many oportunities for development of superior strains of the grass for conservation and other uses.

Big Bluestem and Sand Bluestem. Of all the native grasses in the American prairies, few equal Big Bluestem (*Andropogon furcatus*) and Sand bluestem (*Andropogon halli*) for forage production and soil conservation. They are so readily eaten by grazing animals that they have been greatly reduced since 1885.

Both grasses are erect and leafy, with seed produced on stalks from 2 to 8 feet tall. These grasses reproduce by seed and by creeping, scaly rootstocks. Shoots of big bluestem are attened, leaves are rolled in the bud, lower sheath and leaf blades are often covreed with silky hairs. Shoots of sand bluestream are rounder and usually free of hair.

Andropogon is the classical genus name for the bluestems and is derived from two Greek words, Andros (man) and pogon (beard). Beardgrass is also one of the other common names for bluestem, being a more or less literal translation of the two ancestral Greek words. Most grasses have pithless stems that are solid at the joint. Bluestems are different from most other grasses in this characteristic as the stem cores are pithy like cornstalks.

Big bluestem and sand bluestem are near-relatives of a large tribe of grasses which live in the warm temperate zones of this globe. Big bluestem has been reported in all states except California, Nevada, Washington, Oregon and Idaho, but was originally most abundant in the Middle West and prairies west of the Mississippi Valley from Lake Winnipeg to the Gulf of Mexico. Its western line of importance extended nearly to the 98th Meridian although sometimes found in valley bottoms almost to the Rocky Mountains.

Sand bluestem closely resembles big bluestem and is apparently closely related to it as the two appear to intergrade freely. Sand bluestem is found from the Great Plains states and Iowa to as far west as Arizona, Utah, Wyoming and Montana. It grows consistently on sandy areas but there are notable exceptions as it is sometimes found on loose shales and on the gyp outcrops and clay soils of the Permian redbeds of Oklahoma, Kansas and Texas. It thrives most abundantly in the sandhills adjoining river courses from Monahans, Texas, to Lisbon, North Dakota.

These two grasses usually produce considerable high quality forage before the summer solstice (June 21). Following this, they grow faster as days become shorter and nights longer. Seed development takes place from early September until frost. Deferred grazing is therefore most beneficial during the early growing stages and for two or three weeks following seed production. Grasses store most of their food reserves in the roots after seed has matured. Hay yields run from ½ to 1½ tons per acre, depending upon season and site, although some are higher or lower. Hay yields are apparently not much different in North Dakota than in South Texas when soil and moisture are about equal. Best hay yields thus far determined by the Soil Conservation Service within the Bluestem Belt come from the Red River valley in North Dakota and near Port Lavaca, Texas. The airdry hay yield was about three tons per acre with a slight advantage going to the North Dakota site.

Feeding value of mixed bluestem grasses in comparison with other good grasses is taken from information developed by Texas Experiment station, which is set forth as follows:

Table 1. Percent Protein of Mixed Bluestem and Other Good Texas Grasses at Different Stages of Growth

Stage of Growth	Mixed Bluestems	Mixed Grama	Buffalograss
Samples East of 25" Rainfall Belt			
Young	8.29	8.36	9.34
Medium	6.46	6.36	6.82
Bloom	4.78	5.38	6.53
Mature	3.71	4.59	5.35
Samples West of 25" Rainfall Belt			
Young	11.02	9.42	9.70
Medium	7.50	6.76	7.46
Bloom	5.19	6.36	6.11
Mature	4.01	5.92	6.25

Figure 2. Many years before, someone plowed this land and destroyed the bluestem. The land wore out under poor farming practices. This rancher, near Cheyenne, Oklahoma, planted the land to little bluestem and sideoats grama.

Big and sand bluestem are among the most effective native soil conservation plants in the prairie region of America. Their extraordinary root systems fill the soil from the surface to depths of 6 to 12 feet in well-developed loam soils, hence they can withstand short-time droughts better than the shorter rooted grasses.

The roots and rhizomes or fleshy rootstocks of bluestems and other grasses give the soil considerable defense against water erosion. However, protection to soil by the living foliage and disintegrating litter is far greater. Cutting effect of splashing rain is neutralized when it falls on a good protective cover of grass stubble and litter. Rainwater sinks deep into the soil, safe from evaporation. Soil protected by good bluestem cover may be 30 to 50 degrees cooler than bare soil in summer.

Moisture and temperature conditions are then best for action of invisible soil organisms which promote plant growth. Comparisons made by the Soil Conservation Service and others indicate that bluestems are far superior to short grasses in both foliage and residue production. For example, foliage production was 2½ times and litter production four times as great on bluestem ranges compared to buffalograss range on upland sites near Fort Worth in October, 1946.

Now that better seed sources are being developed, these two grasses are being planted to reclaim eroded lands. They are being used on good farm land, as well as part of a long time crop rotation. Big bluestem is being seeded singly or in mixtures on the better sites between the 98th meridian and the 40-inch rainfall zone.

Sand bluestem has served as one of the best soil conservation plants in stabilizing eroded sandy lands of the central prairies and High Plains. Soil Conservation Service men who helped stabilize sand dunes near Dalhart, Texas, and Caddo Dam near Lamar, Colorado, found that sand bluestem was highly adapted to tying down drifting sand. When given temporary protection from wind erosion by artificial mulches of wheat straw or sorghum stubble, the seed germinate and grow. The grass advances rapidly into surrounding areas by means of seed and particularly by aggressive rootstocks and travel underground send up shoots to form new plants. The wide-spreading fibrous roots bind the soil in place and the litter protects the soil from wind and rain.

Switchgrass. Switchgrass (*Panicum virgatum*) is an erect, robust grass which varies in height from 18 to 60 inches. Leaves and stems are green or purplish; seedheads are often eight to ten inches long and widespreading. There are deep, fibrous, vertical-growing roots as well as white, scaly, creeping rootstocks which occupy the first few inches of the soil.

Switchgrass grows native in all states in the United States except the three on the Pacific Coast. It is also

found in southern Manitoba, Saskatchewan, and Quebec in Canada, and in Mexico and Central America. Area of major abundance corresponds with the bluestem prairie belt. Also, it grows along watercourses and sandy areas. Minor quantities also are found on sub-humid upland prairies. Although it may be found in almost pure stands along watercourses, it makes up a small fraction of the species in the prairies.

Switchgrass ranks high as a soil conservation plant because of its abundant branching rootstocks and fibrous roots which reinforce the soil against erosion. Yield of forage and protective litter is high. Old stems remain erect in winter, thereby protecting the soil and providing an effective snow trap. Soil Conservation Service nurseries have selected strains that are highly rust- and grasshopper-resistant, yet superior for grazing too. Soil conservation district cooperators have used it in the Great Plains in planting contoured grass strips for protection against wind and water erosion. Strains for greater palatability and drought-resistance are being used with success in semi-arid regions as competition from other plants is done away with when pure plantings of switchgrass are made.

Hay yields are comparable to those of big bluestem and Indiangrass and quality is high provided grass is cut during the blooming period. The Texas Experiment Station reports that protein, phosphoric acid, and lime content of the young grass is fair to good; but when mature, the protein content of the grass is deficient, phosphoric acid deficient or just fair, and lime content good.

It serves well for meadow outlets for farm terraces. Although of minor importance in the prairie, it can be maintained for grazing when used correctly. The stalky, coarse bottomland forms are less palatable than the fine stemmed upland types. This is especially true of the Dakota and Oklahoma upland forms which have been selected for meadow and conservation purposes.

Indiangrass. Indiangrass (*Sorghastrum nutans*) is a tall grass that spreads actively from rootstocks. Flowers are in large, yellow panicles which develop from August to November, depending on latitude. Leaf blades narrow down near the sheath and there is a spectacular ligule. Economics, geography, conservation value and ecology of Indiangrass are quite similar to big bluestem.

Comparative Grazing Value of Bluestem Grasses

Whenever a man is in doubt about the comparative worth of different grasses, he should watch carefully to see which ones livestock select at different seasons. Also, he should find out how much animal production is obtained from each grass in order to discover which ones are the most palatable and highest producers.

Let us compare the bluestem grasses with others and find out what experience indicates their value to be. King Ranch bluestem, big bluestem, little bluestem, Indiangrass, sideoats grama, blue grama and buffalograss are some on which we have good information.

In some respects these grasses have common features. All are most palatable and highest in feeding value when young and green; all are least palatable and least nutritious when mature. Livestock eat them all readily when green but protein supplements must be provided animals when grasses are dormant and too low in protein. Livestock make good gains on each of the grasses during the green growing period. All give adequate soil protection if the stand is good and grazing use is right.

However, some react differently to changes in soil and climate. The tall grasses yield more where they are adapted than the short grasses which affects their economic and conservation value.

Of all these grasses, the one we know the least about is King Ranch bluestem, an importation which is native in India and northwest Turkestan. There it is claimed to survive in rainfall belts ranging from 8 to 100 inches per year. In November, 1939, Nico R. Diez, of Soil

Figure 3. Portrait of little bluestem, the most abundant grass in the Bluestem Belt.

Conservation Service Nursery, San Antonio, Texas, selected 75 pounds of the seed from the King Ranch. This strain was named King Ranch bluestem, and seed has been grown on the San Antonio Nursery to provide seed for soil conservation districts in Texas and Oklahoma.

It is not a miracle grass but experience with it on several hundred acres planted on soil conservation districts indicates that it is as good or better than our native bluestems.

David H. Foster, Nursery Manager, Soil Conservation Service Nursery, San Antonio, Texas, says that for a long time stockmen have been searching for a grass that could be scattered from horseback and obtain a successful stand. King Ranch bluestem is one grass that can be broadcast with successful results.

At least several landowners in the limestone hill country west of San Antonio, Texas, have had excellent success with the hand broadcast method where sowing has been on rocky or gravelly soils.

King Ranch bluestem produces a more vigorous and faster growing seedling than most grasses tried. Often it will germinate and mature sufficiently to produce a seed crop the first year. Stand improvement from self-seeding is excellent.

King Ranch bluestem is a good beef producer too. Dick Prassel, owner of the D. P. Ranch near Boerne, Texas, reported he sold three truck loads of calves that were weaned off Hereford cows that obtained most of their feed from King Ranch bluestem. The calves in one truck weighed 584 pounds each, in another truck the individual calf weights were 563 pounds and in the third truck the calves weighed 650 pounds each. These are very good weaner calf weights. Other experiences show that King Ranch bluestem is an exceedingly good beef producer.

King Ranch Strain Adapted to Many Uses

The King Ranch strain also is a top notch conservation grass. The mat forming crown leaves settle close to the ground resembling a coarse wig for a bald head. Under close grazing, leaves and stems grow horizontally close to the ground, a growth habit which does much to perpetuate the grass under heavy use. As a soil conservation grass it is admirable for covering terrace outlets and diversions, on stock water dams, in gullies and drop inlets.

It is adapted to a wide variety of soils and grows well in the Blacklands, Rio Grande Plains, Edwards Plateau, Grand Prairie, Reddish Prarie, Cross Timbers and Rolling Red Plains.

The bluestem grasses are selected first by livestock which make higher gains than do animals on buffalograss where it has invaded ranges in the Bluestem Belt. Cattle and sheep choose the bluestem grasses over buffalograss in the summer but both of these grasses are grazed about equally in winter. The per acre yield of beef from bluestem grass at Stillwater, Oklahoma, was 40 pounds and for buffalograss the per acre beef yield was only 25 pounds. On the Redlands Soil Conservation Experiment Station at Guthrie, Oklahoma, beef produced per acre on native bluestem totaled 63 pounds. Cattle on the Cheyenne, Oklahoma, Land Utilization Project gained 265 pounds per head on the average and the per acre yield of beef from bluestem was 50 pounds. Grazing was from late April to mid-September. Ranchmen near Fort Worth report that spring and summer beef gains from bluestem ranges are about 70 to 80 pounds per acre.

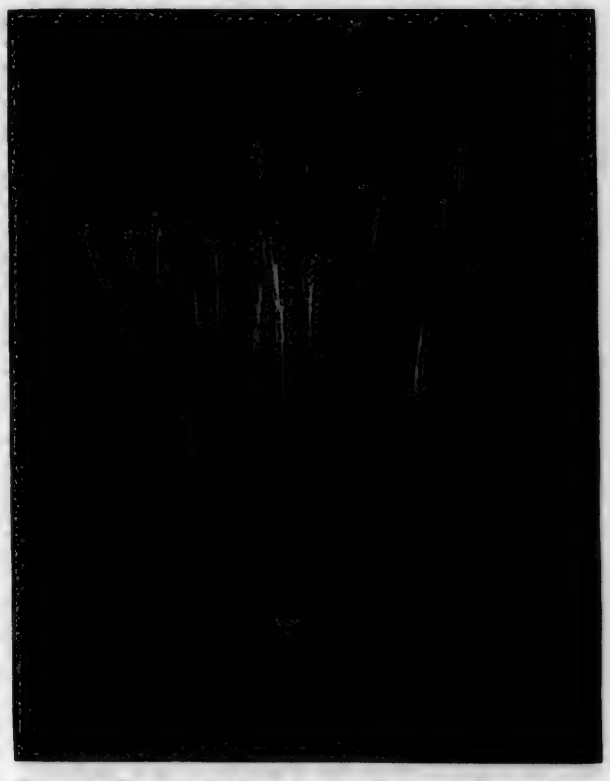

Figure 4. Portrait of sideoats grama, the most robust and productive of the gramas.

Planted mid and tall grasses at the Woodward, Oklahoma, Experiment Station turned off more beef per acre than seeded buffalograss.

For example, the cattle on native bluestem mixture gained 364 pounds per year each and the per acre beef yield was 78 pounds; average gain per steer on buffalograss 357 pounds and the per-acre beef yield was 68 pounds.

Steers on native bluestem on the Blackland Experiment Station, Temple, Texas, have produced 88 to 120

(*Continued on page* 198)

A System of Soil Profile Characterization

R. M. SMITH AND GEORGE SAMUELS

The authors of this article point out that soil is a complex, dynamic body whose present profile properties reflect use and treatment as well as original soil forming factors. Their aim is to standardize observations in order that soil research may contribute more to the practical use of soil resources. To accomplish this, they offer a simplified method of notation and show how to convey comparable concepts to field and to laboratory scientists.

IF SOIL IS TO BE USED as an essential part of any research problem or for agricultural production, the worker must understand and appreciate the soil and its behavior. Since soil is dynamic and complex, its understanding involves interpretation of the action of a number of its fundamental properties. Without a thorough consideration of the major properties of a soil, it is often impossible to find any sound explanation for the response or lack of response obtained from single variables in treatment or use.

Soil has been defined by Joffe as "a natural body of mineral and organic constituents, differentiated into horizons, of variable depth, which differs from the material below in morphology, physical make up, chemical properties and composition, and biological characteristics" (9). Based upon such a definition, any characterization of the important properties of a soil necessitates recognition of the genetic relationship of the horizons as exposed by the soil profile. Marbut (10) was insistent that soil profiles, themselves, must be the real basis for soil classification. Our concept of profile characterization is entirely consistent with this view, but the aim of profile characterization in our case is to understand and interpret soil properties for practical application rather than to merely classify soil as a naturally occurring body.

Management and treatment have altered soil profile properties to such an extent that the soils which we now have are much different from the virgin profiles on which soil type distinctions are based. Therefore, the characterization of soil profiles does not mean that the determination of essential soil properties is limited to the virgin soil; in truth, the use of the virgin profile is but one phase of soil characterization. There are now many important variations caused by man which did not originally exist. It thus appears essential to recognize man as an independent soil forming factor. In some cases, essential equilibrium has been reached between soil decline and soil building under a man-made system of farming. In such cases we have rather definite soil profiles with man as one of the factors. At the same time, there are many cases where present farming methods are merely mining the virgin soil resource and no equilibrium exists between destruction and construction. In these cases the present soil profile is highly temporary. There are also differences within virgin soils which may not have influenced original classification but which become important under intensive soil use. Therefore, research people must evaluate the actual soil properties which exist at locations where experimental work is done, accepting management and natural property variations as essential features of every soil type or mapping unit. And for the same reason that we would not think of using a few leaves to define a plant and its properties, or a few cells to define an organism and its functions, we would not separate a certain soil horizon from its surroundings and give to it the attributes of the entire soil body.

Soil Profiles Influence Land Use and Productivity

In characterizing soil profiles for research and use, we have attempted to define the soil in terms of nine properties. These properties are derived from direct contact with field technicians and farmers and are intended to cover all of the practical information about soil profiles, themselves, which is needed for the most effective use of land. These general properties and the more specific measurements or indices used in defining them are given in Table 1.

The properties used in these profile characterizations normally include a quality or intensity factor, and a quantity factor. Many of the properties can be evaluated directly in the field through profile studies by experienced soil scientists. Others can be measured accurately in the laboratory. In some cases, field and laboratory measurements can be made of the same property. In those cases where the field and laboratory evaluations agree, our assurance is greatly strengthened regarding the results. The ideal is to develop and perfect standard

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George Samuels is associated with the Agronomy Department of the Puerto Rico Agricultural Experiment Station with headquarters at Rio Piedras.

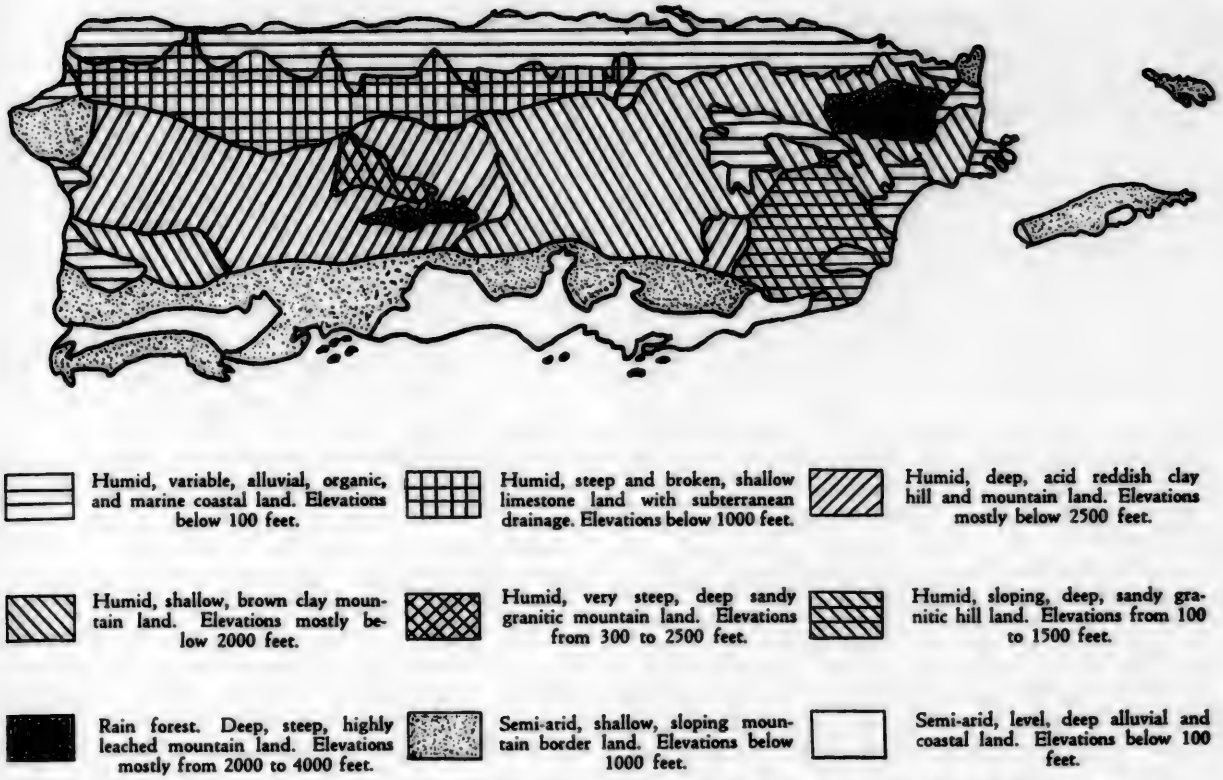
Humid, variable, alluvial, organic, and marine coastal land. Elevations below 100 feet.
Humid, steep and broken, shallow limestone land with subterranean drainage. Elevations below 1000 feet.
Humid, deep, acid reddish clay hill and mountain land. Elevations mostly below 2500 feet.
Humid, shallow, brown clay mountain land. Elevations mostly below 2000 feet.
Humid, very steep, deep sandy granitic mountain land. Elevations from 300 to 2500 feet.
Humid, sloping, deep, sandy granitic hill land. Elevations from 100 to 1500 feet.
Rain forest. Deep, steep, highly leached mountain land. Elevations mostly from 2000 to 4000 feet.
Semi-arid, shallow, sloping mountain border land. Elevations below 1000 feet.
Semi-arid, level, deep alluvial and coastal land. Elevations below 100 feet.

Figure 1. Major Land Use Problem Areas of Puerto Rico (adapted from information supplied by Mr. Juan P. Cordova, Soil Scientist, Soil Conservation Service Operations).

measurements of known meaning for all cases.

It will be noted that certain well known factors such as organic matter, texture, and structure, are here used as indices for defining the directly practical properties, but are not given primary importance for their own sake. This emphasizes the objective: the characterization of soil for practical understanding and use; and at the same time it preserves the integral relation of the soil profile without distorting any one soil property.

Table 1. Major Properties of a Soil Profile which Directly Influence Land Use and Productivity

I. Mechanical Properties
   1. Profile depth
   2. Workability
   3. Erodibility
II. Water Properties
   1. Water movement capacity
   2. Water holding capacity
III. Air Properties
   1. Aeration capacity
IV. Plant Nutrient Properties
   1. Acid and alkaline capacity
   2. Soluble salts
   3. Available nutrients

Definition of the Major Soil Properties

In certain cases it may be unnecessary, but to assure a clear understanding, it seems desirable to define each of the nine major soil profile properties and give their present means of evaluation:

I. Mechanical Properties:

1. *Profile depth:* The distance from the surface to any rock or soil layer which prevents or seriously retards root penetration. In some cases where the percentage of rock increases gradually, the absolute depth may be difficult to decide. It would seem best in such cases to consider depth to solid rock and to evaluate the influence of the loose rock on water-holding capacity.

   Evaluation: Field measurement in inches to rock or impervious layer.

2. *Workability:* The ease with which tillage procedures can be carried out and proper seedbeds prepared. It has much more practical meaning than textural designation, especially in the tropics, where stable clay aggregation is an outstanding quality of many soils.

   Evaluation: Field and laboratory measurement of texture and structure.

3. *Erodibility:* The ease with which soil can be,

first, detached, and second, carried away. This property should be considered separately from slope and from amounts of runoff.

Evaluation: Observable or measurable indices of texture and structure; and measured laboratory indices of organic matter and dispersion ratio.

II. Water Properties:

4. *Water movement capacity* as defined by:

a. Water Intake Capacity: The normal capacity of the soil to admit water to the immediate surface. Different intake values will naturally occur, depending on the wetness of the soil and on the tillage condition of the surface. This will have to be considered in describing the property.

Evaluation: Observable field indices of surface structure and surface texture; field infiltration measurements.

b. Water transmission capacity: The profile capacity to permit water movement under all moisture conditions. In many cases the limiting layer or layers and limiting moisture condition will be given the main consideration.

Evaluation: Observable indices of texture and structure; laboratory measurement of percolation rates.

5. *Water holding capacity* as defined by:

a. Permanent available water-holding capacity (quantity factor): The quantity of available water held after free drainage has essentially ceased (pF 2.7 to 4.2). This is sometimes spoken of as "total available water," but such is obviously not the case, because use of water by plants and slow drainage normally occur simultaneously during a considerable proportion of the time under some soil and climatic conditions.

Evaluation: Laboratory determination of amount of water held from pF 2.7 to 4.2; observation of texture.

b. Tightness with which available water is held (intensity factor): The energy between soil and water throughout the range of availability, commonly expressed by complete pF curves for the different soil layers to pF 4.2.

Evaluation: Laboratory or field determination of total available water

Figure 2. Steep eroding slopes limit the use and productivity of more than half of Puerto Rico, but soil profile characterizations and field experiments are providing answers needed for more efficient use and treatment of the land. Low water holding capacity is a property, second only to slope as a practical factor in the use of this sandy soil from granitic rock.

drained at properly selected pF values.

III. Air Properties:

6. *Aeration Capacity:* The ease with which the soil pore space permits the exchange of gases among soil layers and with the atmosphere.
   Evaluation: Field observation of depth and degree of mottling and laboratory measurement of percent by volume of pores drained at appropriate low pF values.

IV. Plant Nutrition Properties:

7. *Acid or alkaline capacity* as defined by:
   a. *Acid or alkaline intensity (pH)*: This property is defined by the definition of pH.
      Evaluation: pH, laboratory, or field determination.
   b. *Acid or alkaline quantity (Exchangeable H^+)*: This is the buffering capacity of soil, or its resistance to change of pH.
      Evaluation: Laboratory or field measurements of amount of lime or sulfur required to reach a certain soil pH.
8. *Soluble Salts:* The chemical salts which are soluble in water in the soil pore spaces, and whose presence in excess amounts may serve to make the soil unfit for plant growth.
   Evaluation: In arid regions, by laboratory measurement of conductivity, total salts, and exchangeable Na; in humid areas by conductivity.
9. *Available Nutrients:* The capacity of the soil to deliver desired quantities of essential nutrient elements.
   Evaluation: Laboratory measurement of general indices of conductivity, organic matter, cation exchange capacity, and total bases; measurement of primary minerals other than quartz; and specific measurement of P, K, and other ions.

Major Soil Properties and Their Indices Indices

In order to provide a simple and flexible method of expressing soil properties and indices with as much accuracy as is justified, a special notation system has been devised (Table 2). This system is a convenience which offers certain advantages for rapid and practical comparisons among soils or conditions. The use of an intermediate number, 5, to express excellence is a special feature of importance. This permits one simple series of numbers to show deficiency, perfection, and excess of any property or index with a minimum of confusion.

Table 2. Notation System for Soil Properties Which Directly Influence Land Use

				Ideal 5 (Excellent)						
			4	(Good)				6		
		3		(Medium)				7		
	2			(Fair)				8		
1				(Poor)				9		
0				(Very Poor)				10		
Too little or too low or too easy or too loose								Too much or too high or too hard		

Testing Soil Profile Characterization in Puerto Rico

Both the properties themselves and the system of notation have been subjected to testing under Puerto Rican conditions. In Table 3 the directly practical soil profile properties are given, together with the present laboratory and field indices used for their evaluation in Puerto Rico. The table makes use of the notation system for characterizing these evaluated indices. The calibrations of indices used to measure the soil profile properties are based on judgment and on the most accurate measured values available. Chemical fertility indices are derived primarily from data by Bonnet (1-7), Capó (8), Torrent (12), and by Roberts (11), and on some recent unpublished data, as related to general plot and field responses to nutrients. The indices used in this table are by no means complete, but they are the ones which seem to deserve greatest attention under Puerto Rican conditions at the moment. Where measured values are suggested, these are being tested whenever new data become available. This testing consists of checking against field opinions, known field performance, or measured performance under experimental control.

Illustrations of the use of the nine major soil properties in characterizing several well-known soils is given in Table 4. The calibrated notation numbers bring out the differences inherent in the various kinds of soil profiles mentioned.

Another example is given in Table 5, where the system is applied to major problem areas of land use in Puerto Rico. (See Fig. 1). Certain properties can only be described as covering a very wide range. This, however, is merely an expression of fact. It indicates that for the property in question the mapping area is either meaningless or highly variable. On the other hand, properties which are rather specific for the area can be so indicated. This brings out the strength and the weakness of the soils and the mapping distinctions.

Table 3. The Characterization of Major Practical Soil Profile Properties Which Directly Influence Land Use

Soil Profile property	MECHANICAL PROPERTIES							
	1 Profile depth	2 Workability		3 Erodibility				
Means of Evaluation	Field measurement inches to rock or impervious layer	Observable or measurable indices		Observable of measurable indices		Measurable laboratory indices		
		Texture	Structure	Texture	Structure	Organic matter % clay	Organic matter % sand	Dispersion ratio %
0	2							
1	2-10							
2	10-20	Gravel	Single grain					
3	20-36	Coarse sand	Single grain					
4	36-60	Sand	Single grain					
5	60	Sandy or Loamy	Crumb or granular	Clay	Coarse and H_2O stable	6	3	5
6		Silt Loam	Granular or Fine fragmental	Clay loam		4.5-6	2-3	5-15
7		Clay loam	Fine fragmental	Sandy clay		3-4.5	1.5-2	15-30
8		Silty clay	Coarse fragmental	Sand	Coarse and not H_2O stable	2-3	1.5-1	30-50
9		Clay	Blocky	Loam		1-2	.5-1	50-75
10		Heavy clay	Massive	Silt	Fine and not H_2O stable	1	.5	75

Notation

Soil profile property	WATER PROPERTIES						
	4 Water Movement Capacity						
	4a Water Intake Capacity				4b Water Transmission Capacity (Permeability)		
Means of evaluation	Field measured infiltration inches per hour		Observable indices		Laboratory measurement Tightest layer percolation rate in/hour at unit head	Observable indices	
	Moist soil	Wet soil	Structure	Texture		Structure	Texture
0	0.1	0.01	Puddled	Silty clay or heavier	0.01	Silty clay or heavier	Massive clay
1	0.1-0.5	0.1-0.5		Silt loam or heavier	0.01-0.05	Silty loam or heavier	Blocky clay
2	0.5-2.0	.05-.20	Cracking or channels		0.05-0.20		Overlapping fragments
3	2.0-5.0	.20-.80			0.20-0.80		
4	5.0-10.0	.80-2.5	H_2O stable aggregates		0.80-2.50		
5	10	2.5	Large water stable aggregates	Sandy	2.50-10.0	Sandy	Strongly aggregated
6					10.0	Coarse sand	Large Channels

Notation

Soil profile property	WATER PROPERTIES					AIR PROPERTIES	
	5 Water Holding Capacity					6 Aeration Capacity	
	5a Permanent available water holding capacity (quantity)		5b Tightness available water is held (intensity)				
Means of evaluation	Water held from pF 2.7 to 4.2 Inches H_2O/60" profile	Texture	Texture	% of total available water drained at: pF 2.0	pF 3.5	Field index depth to mottling, inches	Lab. index pores drained at pF 1.6 % by volume
0	1	rocky	rocky	85	15	2	0.2
1	1-3	sand	sand	75-85	15	2-10	0.2-1.0
2	3-6			65-75	15	10-20	1.0-3.0
3	6-9			50-65	15	20-36	3.0-6.0
4	9-12			35-50	15	36-60	6.0-10.0
5	12	clay	clay	25-35	15	60	10.0
6				25	15-30		
7				25	30-50		
8				25	50-65		
9				25	65-75		
10				25	75		

System

PLANT NUTRITION PROPERTIES

Soil profile property	7 Acid or alkaline capacity			8 Soluble salts					
	7a Acid or alkaline intensity	7b Acid or alkaline quantity		Arid region				Humid region	
	Laboratory or field measurement				Total salts tons/acre			Conductivity $EC_2 \times 10^5$**	
Means of evaluation	pH	Tons pure $CaCO_3$ or lbs. of S for a pH of 7.0	Conductivity $EC_e \times 10^5$*		Clay soil	Sandy soil	Exch. Na % of C.E.C.	Clay soil	Sandy soil
0	4.0	6						5	1
1	4.0-5.0	4-6							
2	5.0-5.5	2-4							
		$CaCO_3$							
3	5.5-6.0	1-2							
4	6.0-6.5	½-1							
5	6.5-7.5	0-½	0-200	100	1	¼	10	30-50	15-25
6	7.5-8.0		200-500	100-200	1-2	¼-½			
7	8.0-8.5		500-1000	200-400	2-4	½-1	10-15		
8	8.5-9.0		1000-2000	400-800	4-8	1-2			
9	9.0-9.5		2000-6000	800-1500	8-10	2-3			
10	9.5		6000	1500	10	3	15	200	50

System

*$EC_e \times 10^5$ = electrical conductivity in mhos of a water extract of a saturated soil.
**$EC_2 \times 10^5$ = electrical conductivity in mhos of a water extract of 2:1 water-soil mixture, assuming that the balance of soluble ions in the soil solution is normal.

PLANT-NUTRITION-PROPERTIES

Soil profile property	9 Available Nutrients								
	General indices							Specific indices	
	Laboratory measurements							P	K
	Conductivity $EC_2 \times 10^5$		Organic matter in plow layer						
Means of evaluation	Clay soil	Sandy soil	Clay soil	Sandy soil	Total bases $CaCO_3$ equiv. lbs./acre	Cation Exch. Cap. me/100 grams	Primary minerals less quartz, % of sand	Truog method lbs. P_2O_5 per acre	Exchangeable with neutral salt Lbs. K_2O/acre
0	5	1	0.5	0.2	500	1	5	10	25
1			0.5-1.0	0.2-0.5	500-5000			10-25	25-75
2			1.0-2.0	0.5-1.0	5000-10000			25-50	75-150
3			2.0-3.0	1.0-2.0	10000-25000			50-100	150-250
4			3.0-4.5	2.0-3.0	25000-50000			100-200	250-400
5	30-50	15-25	4.5	3.0	5000	20	50	200	400
6									
7									
8									
9									
10	200	50							

System

In addition to these broad, generalized uses, we have found that the typical soil types and phases described by Roberts (11); and the more recently established Soil Conservation Service mapping units lend themselves to similar characterization. Some properties necessarily cover wide ranges and must be so designated. This helps to bring out just what a mapping unit means. The series of numbers make it possible to quickly and easily locate the limiting soil factors in each case.

From a strictly technical standpoint, the best profile descriptions achieved by this system bring out many weaknesses in our present methods and understanding.

Table 4. Some Examples of the Characterization of Definite Mappable Soil Profiles on the Basis of Soil Properties Using a Notation System

Soil	Workability	Erodibility	Profile depth	Water intake capacity	Water transmission capacity	Permanent available water capacity	Tightness available water is held	Aeration capacity	Acid intensity pH	Acid quantity (Exch. H+)	Soluble salts	Available nutrients
Black alkali	9	...	5	1	1	1	9	1	9	1	7-10	5
Deep reddish tropical clay	6	7	5	3-5	4	5	6	4-5	2	8	2	3
Shallow brown mountain clay	6	6	2	5	3	2	7	3	4	6	5	4
Loose coastal sand	4	...	5	5	5	1	1	5	2-3	4	...	1

Figure 3. Structure is a major clue in soil profile characterization. Coarse, stable clay clods, as shown here in a seedbed for tropical kudzu, are resistant to erosion and permit rapid water intake. But workability is difficult because the structure is too coarse. The soil would be rated "5" on erodibility and water intake, but "8" on workability by our system.

This focuses attention on the best and the worst in profile characterization. In our own experience, the system may be credited with definite improvements in our interpretations. It has introduced new ideas for improved methods of evaluating such properties as water intake, water transmission capacity, and workability, in relation to types and degrees of soil structural development.

Summary of Soil Profile Characterization

A brief summary of the present status of soil profile characterization as outlined in this paper is as follows:

(*Continued on page* 198)

Table 5. Characterization of the Soil Profiles Typical of Nine Major Problem Areas in Puerto Rico on the Basis of Essential Soil Properties

Mapping areas	MECHANICAL			WATER			AIR		PLANT NUTRITION		
	Profile depth	Workability	Erodibility	Water intake capacity	Water transmission capacity	Permanent available water capacity	Tightness available water is held	Aeration capacity	Acid intensity pH	Acid quantity	Soluble salts	Available nutrients
I Undiff. alluvium humid coast	0-5	3-5		5	2-6	0-5	0 6	0-5	0 7	3 7	5-8	0-5
II Shallow steep limestone humid	0-2	5-8	5-7	5 6	4-6	0-2	6-8	4 5	5	5	5	3-5
III Deep, red clay mt. land	5	5-8	6-9	2-4	4-5	3-5	5 6	3-5	1-3	7-10		1-3
IV Shallow brown clay mt. land	1 4	5-8	5 8	3-5	1-4	1-3	5-7	3-5	4-5	5-7	4-5	3-5
V Utuado steep sandy mt. land	3-5	5	6 8	4 5	3-5	1-3	3 4	5	3-5	5-7		3-4
VI Granitic rolling sandy mt. land	3-5	5	6-8	4-5	3-5	1-3	3-5	4-5	3-5	5-7		3-4
VII Deep clay soil-rain forest	4 5	5-9	7-9	2-4	1-4	3-5	4-6	2 4	0-3	7-10		0-3
VIII Deep soils semi-arid	4-5	5-10	5-8	0-5	0-5	2-5	4-10	0-5	5-10	5-10	5-10	3-5
IX Shallow soil, semi-arid, steep	0-3	5-8	8-10	2-5	2-5	0-3	5 8	5	4-6	4-6	4-6	3-5

Weeds—Water Robbers

ROBERT B. BALCOM

A weed, as the author points out, is "a plant out of place." It steals water in tremendous quantities which is needed for irrigation, industrial, urban and other purposes. Mr. Balcom tells us how much water certain weeds and deciduous plants use in terms of acre-feet and the relationship of these losses to alfalfa and other crops. Corrective measures involve the use of grasses to replace the weeds. They use much less water and provide additional pasture for the land owner. Soil erosion is also controlled.

NATURE'S "WATER ROBBERS," whose depredations cost the American irrigation farmer an estimated 25½-million-dollar loss each year, are the special target of weed control and eradication studies by the Bureau of Reclamation in cooperation with other Federal, State, and private agricultural scientists.

A weed, in popular parlance, is *"a plant out of place,"* and when plants that serve no economic purpose steal water which could be used beneficially for irrigation, municipal, industrial, and power supplies they are certainly out of place and can rightfully be called weeds.

In the semi-arid West, conservation of water has a special meaning because without irrigation there could be no intensive agriculture. Moreover, the phenomenal growth of the West makes it doubly important that the limited water supply be developed properly and every effort made to stop preventable losses of this precious resource.

The Bureau of Reclamation, which has the responsibility for developing Western water resources for irrigation and other purposes, has made studies of means which could be employed to prevent such water losses. As a result, more efficient methods, including sprinkler irrigation, are being tested and lined canals and closed pipe systems are more widely used to prevent seepage and evaporation losses.

But perhaps the biggest surprise came from the results of preliminary investigations of the loss of water due to weeds. Such losses are sustained not only on the irrigation systems and reservoirs but also on the farmers' fields.

All living plants are miniature pumps, drawing up water through their roots and giving it off again into the air—a process known as transpiration. While all plants utilize water in this manner, in general those species usually thought of as weeds use larger quantities in their growth processes than most cultivated plants. This is the reason why weeds have been called "water robbers" when growing with crop plants. When weeds are allowed to grow in a crop, much more irrigation water is required.

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Water Losses are Heavy

While water losses caused by weed growth on and in ditches were assumed to be considerable, heretofore there were no figures on which to base this assumption. But now, with the aid of the Bureau's survey, it is estimated that nearly 150,000 acre-feet of water is lost each year in the Bureau of Reclamation's 14,075 miles of canals and laterals. This is almost enough to fill reservoirs like the Barlett on the Salt River Project, Arizona; the Deer Creek on the Provo River Project, Utah; or the Green Mountain on the Colorado-Big Thompson Project in Colorado. It is nearly three times more water than was delivered to the farms on the Orland Project, California, in 1947; nearly twice as much as delivered to the Grand Valley Project, Colorado; and more than the combined amount delivered to the Sun River and the Milk River projects in Montana.

These figures do not include the robbery by salt cedars from rivers where our water supplies are obtained, or from reservoir areas like McMillan in New Mexico where they filch about 60,000 acre-feet of water each year. Nor do they figure the loss along private irrigation systems which would multiply the total several times over.

It is difficult to set a dollar value on irrigation water because it varies considerably between localities. However, it would not be unreasonable to assign to irrigation water an average gross productive value of $20 per acre-foot. At this value, plus the costs for ditchbreak repairs and damage to flooded crops attributed to weeds, the total loss on irrigation systems built by the Bureau of Reclamation would be nearly $3,000,000 annually.

To obtain a better idea of the gross productive value of the lost 150,000 acre-feet of water, let us compare it to actual project records. This is approximately the amount of water delivered in 1947 to the Sun River Project, Montana, and the Carlsbad Project, New Mexi-

co, combined. These two average projects, one in the north and the other in the south, together produced, that same year, crops with a total gross value of nearly 5½-million-dollars.

If we project these water losses to all irrigation in the 17 Western States, using the 1940 census figures of 120,386 miles of unlined canals, we arrive at an estimated water loss of over 1¼ million acre-feet annually with a gross value of nearly $25,500,000 if the conservative value of $20 per acre-foot is applied.

Every effort should be made by irrigation farmers to prevent this loss. Even on projects where water is plentiful, he must pay the cost of the extra water needed to supply the weeds and the extra costs required for the operation of the system. During seasons when the water supply is limited, the weeds take their share first and the crop plants may be reduced both in quality and quantity.

For example, a heavy stand of lambsquarters uses 40 percent more water than alfalfa, one of the heaviest water users among crop plants. One acre of polygnum or smartweed may consume in one season's growth enough water to grow three acres of alfalfa. While the weeds are robbing the crops of its water, they are competing for light and plant food which further reduces the farmers' profit.

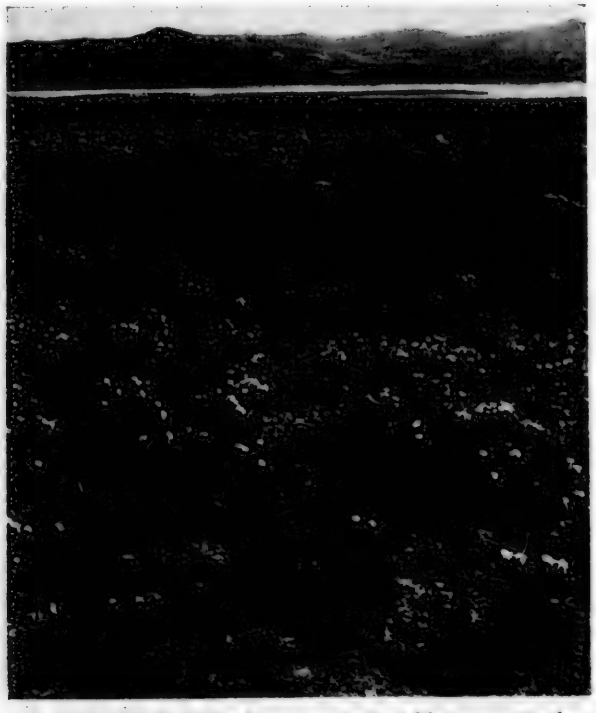

Figure 1. Weeds, like this pasture of prickly poppies, reduce crop quantity and quality through competition for light, plant food and water. Weeds take their share of water first.

The serious problems, other than water loss, that are created by various kinds of weeds growing in ditchbanks and in irrigation channels are well known. The enormous volume of these growths chokes the ditches and reduces their capacity until finally some method of elimination must be employed in order to deliver sufficient water to farmers' crops. Also costly dredging operations often are necessary to remove silt which these growths cause to be deposited in the canals. Many other adverse results of weeds growing on or in the ditches (which are discussed in the Bureau of Reclamation's publication *Control of Weeds on Irrigation Systems*) are in plain view of any observer. However, some of the effects of these growths are not so easily seen and therefore often go uncounted.

Let us look at the water losses caused by weeds on the irrigation distribution system—potential irrigation water which is lost before it reaches the farmers' fields. Transpiration accounts for the greatest part of this loss.

Lambsquarters and smartweed, as well as a host of other common weeds, on ditchbanks use large quantities of water during their growth process. Plants growing in the channels with their stems emerging through the water like cattails, tules, and watercress consume even more. In tests made to determine the consumptive use of tules and cattails, it was found that 15 or more acre-feet of water per acre of plants may be used in a single year, particularly when they grow in narrow strips as often happens along irrigation ditches. They are thus more exposed to the sun and air currents and transpire relatively larger quantities of water than when growing in dense patches. Many weeds can adapt themselves to a small amount of water, but the more they have, the more they use. When they grow along canals and laterals where the water supply is abundant they take a good, long drink.

In addition to the plants usually called weeds, willows and other woody plants are often prevalent on irrigation systems. They send their extensive roots down into the banks and draw heavily on water that may be seriously needed for crops.

Other Factors Affecting Water Losses

Temperatures, humidity, and number of hours of sunshine affect the rate and amount of transpiration from plants. Therefore, the water lost through transpiration in the Southwest is greater than in the more humid, cooler areas further north. Besides the water losses caused by transpiration, emergent and submersed water weeds, and deposited silt raise the water to a higher level in the canal and increase water losses from extra evaporation and seepage. The additional evaporation is in direct proportion to the additional water sur-

face exposed. On an average ditch with a 1½ to 1 slope, each one foot rise in water level increases the total surface width by three feet. It is not unusual for a dense growth of submersed waterweeds to raise the level of the water in a canal two to three feet, thus increasing the surface width six to nine feet. For every mile of ditch, an 8¼-foot increase in width exposes an extra acre of water surface.

The raising of the water level causes additional seepage in three ways. First, the wetted perimeter or area occupied by the water in the channel is increased, thereby exposing a greater area of earth where seepage can take place. Second, the increased depth makes the water column heavier, adding more pressure to the water, and forcing more water into the soil on the sides and bottom of the channel. Third, the higher water level brings considerable water in contact with the upper portion of the banks which is less compact and therefore more susceptible to seepage. Also there is more chance of rodents leaving holes in the upper part of the banks which will cause a loss of water, if not a more dreaded result—a ditchbreak.

Ditchbreaks are also caused by overflows, which result when weeds choke up the water to full capacity and then additional water enters the ditch. This extra water may be from flash rains, waste water from fields, farmers completing their irrigating and shutting off their heads of water, or the ditchrider not being familiar with the "bank full" condition at some point and trying to force more water down the ditch. Ditchbreaks not only result in loss of water, but also in costly ditchbank repairs and damage to flooded crops.

Large weeds like sweetclover cause additional seepage when their roots die and decay forming small tunnels in the soil through which the water easily flows.

One of the most interesting points revealed in the whole survey of water losses was that projects which had a considerable area of their ditchbanks covered with grasses and pastured with livestock reported only a small fraction of the average transpiration loss estimated for all projects. This should be expected, as grasses are comparatively shallow-rooted and some are particularly efficient in their use of moisture, therefore, transpiring much less water than some of the deep and extensively rooted weeds. Experience also has shown that a grass-covered, pastured ditchbank reduces weeds and erosion to a minimum and results in very low operation and maintenance costs. Of course pasturing ditches has a dual advantage—while it is doing such an effective and economical weed control job, it is making money for the project farmer who has the good fortune to be able to take advantage of the ditchbank pasture.

In addition to the water losses created by weeds on croplands, and on the irrigation systems, large quantities of potential irrigation, municipal and industrial water supplies are lost by transpiration from undesirable vegetation growing on natural drainage channels and on reservoir areas.

Figure 2. Salt cedars, cattails and waterweeds create operation and maintenance problems as well as using large quantities of water.

The greatest losses from such areas, without doubt, are caused in the Southwest by the introduced deciduous species of tamarisk shrubs known collectively in that area as salt cedar. The most common species is *Tamarix gallica.* The evergreen tree species of tamarisk (the ahtel tree, *T. aphylla*) was probably transported as cuttings or seed from the Old World by Catholic Padres to beautify and furnish shade for the early missions and schools in the arid Southwest. However, the deciduous species, that are causing the trouble probably were introduced about 1906.

These plants have spread with alarming rapidity, until nearly every natural drainage channel and reservoir area in the Southwest has from scattered patches to dense stands of salt cedar. They have not only usurped water supplies, but also have created flood hazards and taken over lands that could be reclaimed for grazing, agricultural, and other economic purposes.

As the study of acreage infestation and water losses due to salt cedar was started just recently, only rough estimates are available at this time. However, incom-

Figure 3. Grasses control weeds and erosion and use much less water than weeds. It is the aim of irrigation projects to seed all their canal banks as quickly as possible.

plete reports indicate that in the southern parts of California, Nevada, Arizona, New Mexico, and part of Texas there are probably over a half-million acres of salt cedar which are consuming close to 2½ million acre-feet of water annually.

It is realized that the removal of all salt cedar would not automatically release the total amount of water transpired by these growths for irrigation and other water supplies. A portion of the water thus saved would be lost through evaporation and seepage in transit and some would be utilized by seedings of grass and other plants to create better land uses for the previously infested areas. However, if only half of the losses could be converted to beneficial use, it would alleviate a critical irrigation shortage in certain areas of the Southwest.

While the need for water conservation through the control of undesirable vegetation has only recently been fully realized, the Bureau of Reclamation has taken definite steps to stop the leaks wherever possible. In addition to controlling weeds to give more efficient operation and maintenance of its irrigation systems, more permanent methods of control are being developed to reduce future costs and water losses. The Division of Weed Control Investigations of the Bureau of Plant Industry, Soil and Agricultural Engineering of the Department of Agriculture has been cooperating in a research program for this purpose. Also findings made at State Experiment Stations are put into practice. This information is made available to private as well as Federal irrigation projects.

Because of the water loss due to salt cedars, the Bureau is vitally interested in a program for their control. Discussions are being held with other agencies interested in the problem to help develop a plan for the elimination of this water-robbing pest. If left uncontrolled, the plants will continue to spread and make even more serious inroads in water supplies and land resources, and continue to create more dangerous floods hazards during the not-too-uncommon cloud bursts experienced in the Southwest.

Water and Our Forests

Plant cover, soil, and stream flow on a watershed naturally tend to be in balance, if undisturbed. When a large portion of the plant cover, litter, or humus is destroyed by fire, or removed by destructive logging or trampled by grazing animals, marked changes appear. Exposure of the forest floor to wind and sun is increased. Trees break or blow down. The remaining litter and humus dry out, and the busy organisms at and below the surface gradually disappear. Soil becomes more compact and resists the entry of water, so that erosion often begins. The result is a seriously unbalanced forest community that permits less water to be taken into and stored in the soil than before—to the detriment of downstream farms, towns, and cities.

—BERNARD FRANK AND CLIFFORD A. BETTS

From Water and Our Forests

Effect of Land Use Practices on Ground Water

H. W. LULL AND E. N. MUNNS

Water shortages reported during the past few years emphasize how little we actually know about this important resource. Basic in the lack of knowledge is the effect that land use practices have on our ground waters. The authors have made a thorough study of the situation and report their findings with the hope that greater emphasis will be placed by all concerned on land use practices as a means of restoring ground water.

PUBLIC RECOGNITION of a natural resource is seldom granted until a shortage is either experienced or imminent. Water, the most abundant of resources, has now reached this status. In so doing, it is joining the less abundant resources—mineral, forest, soil, and wildlife which have previously gained attention. In the past few years water has received front page notice. We have only to recall the New York water shortage, widespread reports of declining ground water supplies, cloud-seeding experiments, the grounding of the battleship Missouri, the question as to whether upstream irrigation would dry up the lower Missouri, the increasing emphasis on pollution, the sedimentation of our reservoirs. All these reveal a new public interest in the water. Such subjects also reveal how little we actually know about our water resource: what it is, where it is, how much is there. One of the most evident of our lacks in basic knowledge deals with the effect of land use practices on our ground waters.

Land conservationists have not wholly neglected the water resource. But it has taken a back seat to the erosion problem, water being considered principally as the agent of erosion. Emphasis has been placed on the control of surface runoff with little attention being paid to where the water may go. Too often overlooked has been the fact that the same land conservation practices which conserve soil, also conserve water. The primary objective of these practices, to get water into the soil rather than to allow it to run across and erode the soil surface, also permits more water to enter and pass through the soil and into the ground water reservoir.

These underground reservoirs are a vitally important source of water supply, nationally and locally. Not only are they tapped to furnish water for irrigation, industry, and domestic uses, they also are the source of springs and seeps which provide streamflow during dry periods.

Use of ground water has increased rapidly in recent years. Pumping of water from wells in the United States doubled in the period 1935-1945 from 10 billion gallons of water per day to 20 billion gallons of water (17). Guyton (9) has estimated use in 1945 to be as follows:

Class of use	Millions gal./day
Irrigation	10,000
Industrial, not including water supplied from municipal systems	5,000
Municipal	3,000
Rural, not including irrigation	2,000
Total	20,000

According to Langbein (12), 66 percent of all the municipal water supply units obtain their water from wells. These produce 24 percent of the entire volume of water used by municipalities. All in all, an estimated one-sixth of the total volume of water used comes from ground water supplies.

About ten percent of land under irrigation obtains water exclusively from ground water sources. Another ten percent uses both surface and underground water, drawing on surface supplies when they are available, and when they run dry, pumping water from wells. In the Great Plains alone, more than 20 percent of the irrigated area gets its primary supply from wells. (22).

No accurate estimate can be made as to the proportion of water used by industry that comes from ground water. Very rough estimates have been made that 35 to 45 billion gallons per day are pumped for industrial purposes. Accepting this estimate, ground water furnishes from one-seventh to one-ninth of all water used by industry.

The increased use of ground water has lowered the water table in many localities, providing the basis for fears of ground water shortages. Most if not all of these recessions are directly attributable to use. Generally speaking they can be considered a natural phenomenon and should not be viewed with alarm unless supplies are

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pumped faster than they are recharged (17). This of course has happened and is happening in many areas today.

Wholly apart from the effect of pumping on ground water supplies is another question: What are the effects of land use? Our ignorance on this subject reflects the previous lack of interest of conservationists on the subject. It lies at the root of the current controversy as to the true effects. It is time then that we look into the matter. What are some of the effects? What are some of the possibilities?

Characteristics and Source of Ground Water

Ground water is that water which occurs in a zone of saturation beneath the land surface in which all openings are completely filled with water. Normally this zone lies below the true soil layer (solum) or below the root zone.

Depth to the water table varies considerably. In swampy areas the water table intersects the land surface and lies above it. In some areas, it may be found on top of some impermeable material at a shallow depth. This water may represent an accumulation from relatively recent precipitation. In other areas, the water table may lie at a great depth and represent the concentrations of many years, if not many centuries, of unrecorded storms. The intersection of the water table with stream channels accounts for the maintenance of streamflow during those periods when there is no immediate surface runoff from rainfall or melting snow.

The principal source of ground water is precipitation that infiltrates into the soil and passes downward into the subsurface reservoir. The amount of ground water recharge from any rainstorm repends on the amount of rainfall, the infiltration into the soil, the percolation through it, and the amount of water needed to satisfy the soil's storage capacity. Before any recharge can begin, the soil's storage capacity must be satisfied. Significant recharge is largely limited to long duration storms or prolonged snowmelt periods. Ground water recharge also comes from streams, lakes, and reservoirs.

The rate at which ground water recharge takes place depends upon the minimum rate of water movement through the least pervious material. It is aided in part at least, by the hydrostatic pressure of the weight of water in the soil materials above it.

When downward percolating water meets less permeable material, it "piles" up, building up a temporary water table, until it is forced to work its way laterally across this layer. It flows through the soil mass until it reaches an outlet at the surface where it becomes streamflow, or until it reaches permeable material into which it can sink. Ground water is also discharged artificially by any man-caused intersection with the zone of saturation as by drainage, deep cuts, gullying or wells.

Where Water Goes in the Soil

Water that enters soil can move in several directions. Some moves upward. It is returned to the air by evaporation or through vegetation. Some moves laterally through the soil as subsurface flow reappearing as stream flow. A portion moves downward through the soil mass and into the ground water reservoir.

Precipitation that does not enter the soil follows a less circuitous route. It moves across the soil as surface flow, collects into rills and then flows into the channels which carry it away. From the standpoint of water required for the growth of vegetation and for recharge of underground supplies, most of that which goes into surface runoff can be considered as a major loss.

The first limiting factor, then in recharging ground water supplies from precipitation is the direct entrance of water into the soil. In great measure, the effect of land use practices on ground water depends on the extent to which these practices modify the soil so as either to hinder or facilitate the movement of water into it.

The second limiting factor is the porosity throughout the entire soil depth. The more porous the soil, the more rapid the rate of percolation. Porosity and percolation are most favored by land use practices which promote a vigorous root system and which add organic material to the soil. The roots provide channels for downward movement of water. The organic material, by reducing density of the soil, makes it more porous, and in addition makes possible the development of a structure in the soil which facilitates water movement.

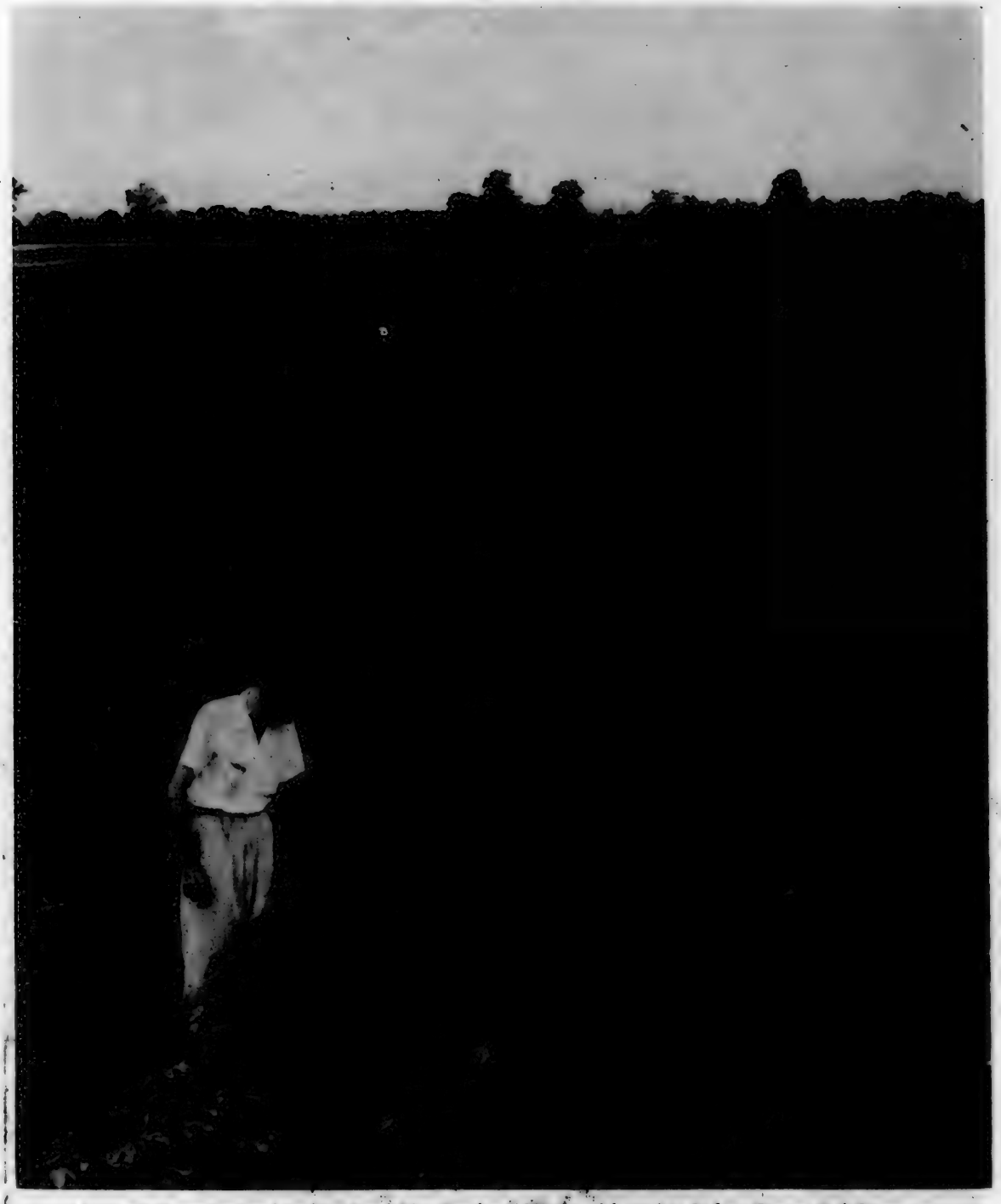
The third limiting factor is the water storage opportunity of the soil. Storage space is made available by the removal of water from the soil by evaporation and transpiration. The storage opportunity depends not only on the rate of removal but also on the depth to which this drain takes place, or, more simply, the depth of the rooting system. Therefore, land use practices that affect either the rate of evapotranspiration or the depth to which the rooting system reaches, affect ground water recharge.

Erosion and Ground Water

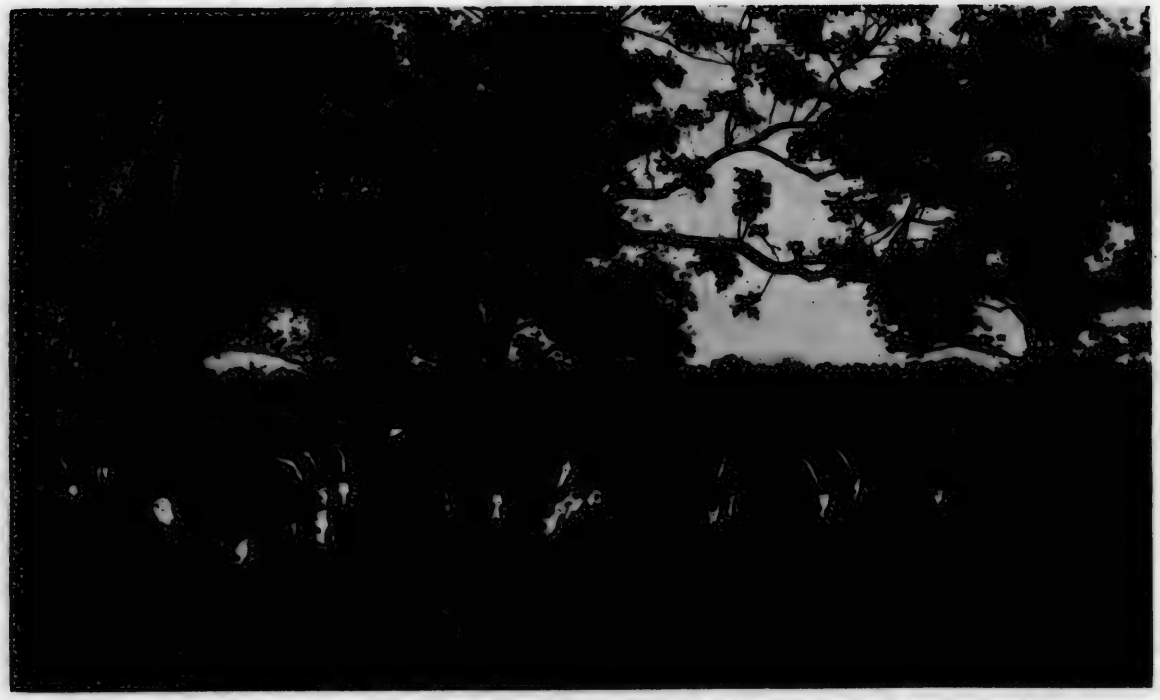
The history of land use in this country is principally one of land mismanagement. The story is familiar: need for land was great, land was plentiful, the soil fertile; when fertility had been exhausted, more land was available. This situation persisted up to near the end of the 19th century.

By 1890 with the greater part of the public domain settled the "new lands" gave out. Depleted soils could

Land Use Changes in the Mississippi Delta

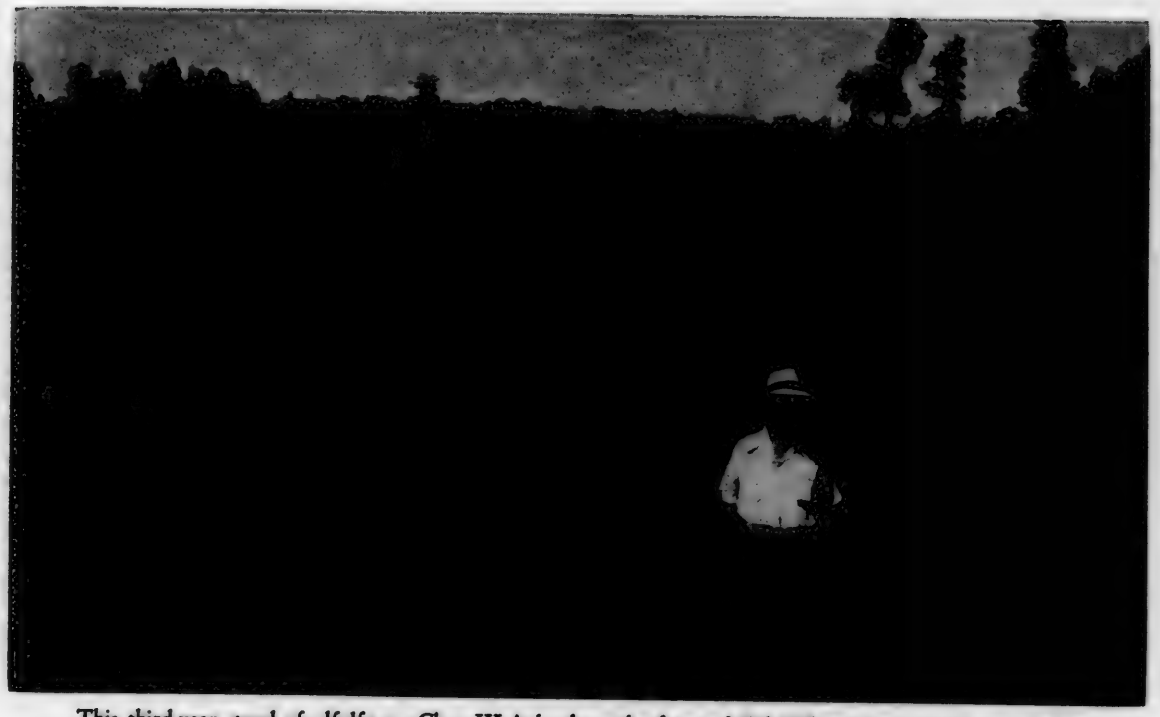


A pictorial presentation based on Land Use Emphasis Week, celebrated in Leflore County Soil Conservation District in Mississippi, August 20-26, calls attention to *the rapidly changing agricultural pattern* in the Mississippi Delta brought about by using and treating the land according to its capability. Cotton, seen here on Class I land, is now only one of the important crops in the Delta. *Photographs are by the Soil Conservation Service.*



Here on the farm of C. E. Humphries, this sandy loam, Class II land is producing both pecans and beef. The white clover and Dallis grass pasture in the pecan grove, with adequate applications of lime and phosphate, is furnishing excellent grazing for a sleek herd of Hereford cattle.

This dense growth of three-year-old sericea lespedeza on Class II land on the farm of G. W. Greene has been harvested for hay and is now growing out a seed crop. This dense growing, perennial legume provides year-round protection for the land, as well as hay, grazing, and a cash seed crop.



This third-year stand of alfalfa on Class III-A land on the farm of Sid Gillespie was given an application of five tons of lime and fertilized with 300 pounds of potash and 25 pounds of borax per acre. The first cutting of hay yielded two tons per acre.

Sheep production is becoming increasingly important in the Delta with the development of good pastures. This Class IV-W land, planted five years ago to white clover and ryegrass, is providing good grazing for this flock of Hampshires.

Fields that once produced only cotton now are providing green grazing the year around. This seven-year-old white clover and Dallis grass pasture is on the farm of W. L. Craig.

Kudzu has come into the Delta not only as a hay and forage plant but is doing an important job along the banks of drainage canals. By suppressing other forms of vegetation along the ditch banks it has greatly reduced the maintenance work on main drainage canals.

no longer be traded for fertile. Not until the late 1920's and the beginning of the '30's, however, was there general recognition that ordinary land use practices had seriously damaged the soil and water resources. By then, these practices which had depleted the soil, left the soil unprotected and speeded surface runoff, had taken a terrific toll. The first comprehensive survey, in 1934 (24), showed that for the entire land area of this country, 37 percent had been slightly eroded with less than 25 percent of the original surface soil lost; 41 percent had suffered moderate erosion with 25 to 75 percent of the soil gone; 12 percent had been severely eroded with loss of more than 75 percent of the topsoil; the remaining ten percent included land destroyed by erosion, and rough mountain land (Figure 1).

These average values cannot adequately portray the tremendous volumes of soil that have been washed away. Gullies, some over 100 feet in depth, have wholly destroyed some 80 million acres of cropland (2). And with the soil have gone great quantities of organic matter and plant nutrients. In most soils of the Missouri Basin, for instance, it has been estimated that 30 to 50 percent of the original nitrogen and organic matter has been lost by decomposition and erosion (22). With this loss, infiltration, one of the limiting factors of ground water recharge, has been seriously reduced.

The extent of erosion by ground water provinces is given in Table 1. Twelve of the 21 provinces have over half of their area moderately and severely eroded. Only two of the provinces do not possess areas which have been severely eroded.

This enormous loss of soil from the landscape was accompanied by an even greater loss of water, for it takes large quantities of water to move soil. How much has thus been lost, no one knows.

Table 1. Erosion by Ground Water Provinces

Province	*Slight or None* Percent of Province	*Moderate* Percent of Province	*Severe* Percent of Province
Atlantic Coastal Plain	45	44	11
Northeastern Drift	81	19	0
Piedmont	7	37	56
Blue Ridge-Appalachian	31	46	23
South-Central Paleozoic	22	55	23
North-Central Drift-Paleozoic	42	40	18
Wisconsin Paleozoic	17	78	5
Superior Drift-Crystalline	78	22	0
Dakota Drift-Cretaceous	61	28	11
Black Hills Cretaceous	70	26	4
Great Plains Pliocene-Cretaceous	40	38	22
Great Plains Pliocene-Paleozoic	33	51	16
Trans-Pecos Paleozoic	20	76	4
Northwestern Drift-Eocene-Cretaceous	78	20	2
Montana Eocene-Cretaceous	63	29	8
Southern Rocky Mountain	63	35	2
Montana-Arizona Plateau	27	49	24
Northern Rocky Mountain	76	23	1
Columbia Plateau lava	32	52	16
Southwestern Bolson	23	65	12
Pacific Mountain	60	37	3

An indication of the comparative magnitude of the

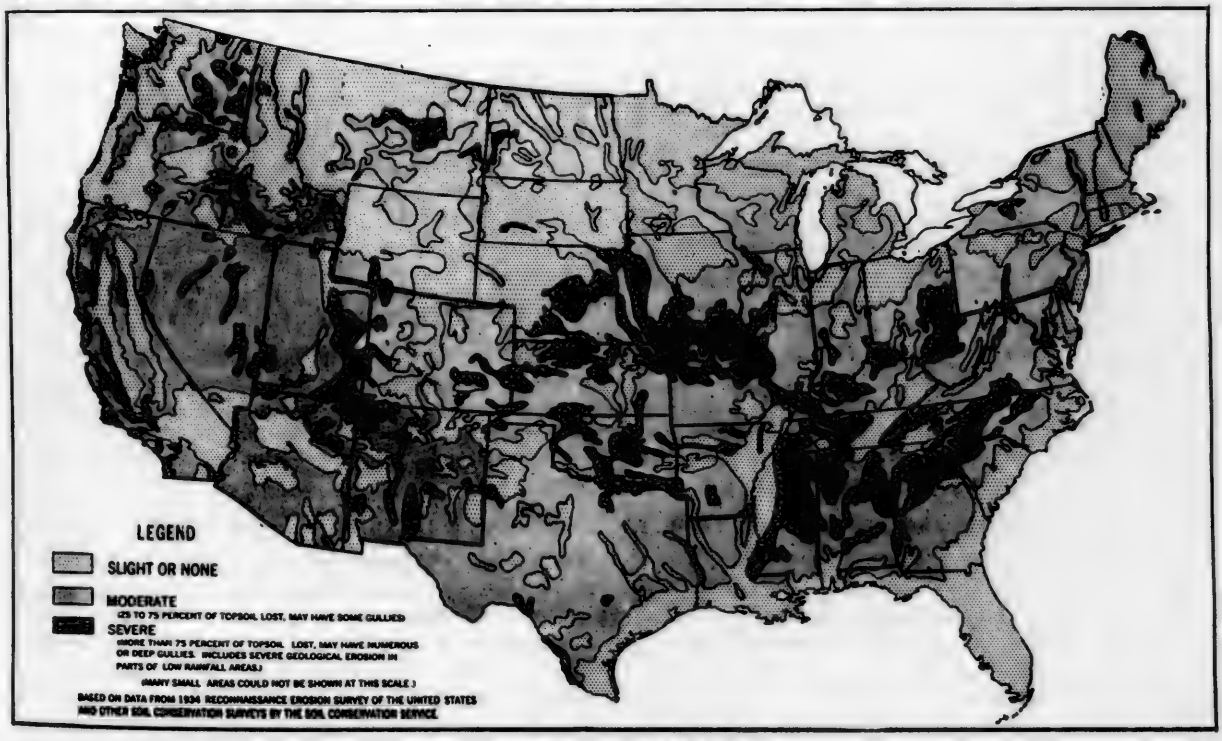

LEGEND
SLIGHT OR NONE
MODERATE
(25 TO 75 PERCENT OF TOPSOIL LOST, MAY HAVE SOME GULLIES)
SEVERE
(MORE THAN 75 PERCENT OF TOPSOIL LOST, MAY HAVE NUMEROUS OR DEEP GULLIES. INCLUDES SEVERE GEOLOGICAL EROSION IN PARTS OF LOW RAINFALL AREAS.)
(MANY SMALL AREAS COULD NOT BE SHOWN AT THIS SCALE.)
BASED ON DATA FROM 1934 RECONNAISSANCE EROSION SURVEY OF THE UNITED STATES AND OTHER SOIL CONSERVATION SURVEYS BY THE SOIL CONSERVATION SERVICE.

Figure 1. Generalized Soil Erosion

Table 2. Volume of Soil and Water Losses from Clean-Tilled Cultivation of 13 Important Soils.

Soil, location, & years of measurement	Annual rainfall for period, In.	Soil loss annually, tons per acre	Water loss annually, % precipitation	Water loss for period, inches	Volume of water loss, cu/ft/ac	Vol. soil loss, cu/ft/ac	Ratio of water vol. to soil vol.
Cecil s.cl.l., Statesville, N. C. 1932-1936	48.42	25.08	10.47	5.07	18,404	627	29:1
Nacogdoches f.sdy.l., Tyler, Texas 1932-1936	42.34	8.18	16.48	6.98	25,337	204	124:1
Kirvin f.sandy loam, Tyler, Texas 1932-1936	41.77	30.07	22.23	9.29	33,723	752	45:1
Shelby silt loam, Bethany Mo. 1931-1935	34.79	68.78	28.31	9.85	35,756	1,720	21:1
Muskingum silt loam, Zanesville, Ohio 1934-1936	36.46	72.23	41.95	14.46	52,490	1,831	29:1
Clinton silt loam, LaCrosse, Wisconsin 1933-1935	34.12	88.66	20.84	7.11	25,809	2,216	12:1
Dubuque silt loam, LaCrosse, Wisconsin 1934-1935	36.53	81.44	19.12	6.98	25,337	2,036	12:1
Vernon f.sandy loam, Guthrie, Oklahoma 1930-1935	33.12	24.29	14.22	4.71	17,097	607	28:1
Houston blk.cl., Temple, Texas 1931-1936	32.76	23.83	14.22	4.66	16,916	596	28:1
1933-1936	34.90	10.62	13.38	4.67	16,952	266	64:1
Marshall silt loam, Clarinda, Iowa 1933-1935	26.82	18.82	8.64	2.32	8,422	470	18:1
Palouse silt loam, Pullman, Wash. 1932-1935	21.74	8.52	9.40	2.04	7,405	213	35:1
	21.74	27.82	25.03	5.44	19,747	696	28:1
Colby silt cl.loam, Hays, Kans. 1930-1935	20.36	11.74	16.20	3.30	11,979	294	41:1
Miles clay loam, Spur, Tex. 1936-1937	20.37	7.03	15.53	3.22	11,689	176	66:1
Averages		33.87	18.40				

s.cl.l. = sandy clay loam; f.sdy.l. = fine sandy loam; blk.cl. = black clay; silty cl. loam = silty clay loam.

volume of soil and water losses is given in Table 2. Data from numerous research stations and areas (2) were used to calculate the volumes of water and soil lost from clean-tilled areas. These show that the volume of water lost is from 12 to 124 times greater than the volume of soil eroded.

This water ran across the uncovered land without opportunity to enter the soil and recharge ground water supplies. This is the result of land use practices which fail to protect the soil. Research has not only shown this to be true, but it has also found why it happens and has convincingly demonstrated that when land is properly protected, soil and water remain.

The increase in surface runoff, as evidenced by the extent of erosion, must have been accompanied by a decrease in ground water recharge. In early settlement days, the ground water must have been at its maximum. With destructive land use, gullying, and drainage, the water table level over large areas must have been reduced. No other interpretation is possible!

Surface Runoff and Ground Water

Since about 1930, many studies of soil and water conservation have been made by Federal and State institutions. By 1939 it was estimated that approximately 50,000 measurements had been made of the effects of individual storms and snowmelts on surface runoff and erosion (2).

This figure has probably been more than doubled today. These measurements have been augmented by many thousand observations made with portable "rainmaking" equipment, (infiltrometer). Studies have encompassed a great variety of various land use practices under a wide range of geologic, soil, topographic and climatic conditions. Consistently they have shown that surface runoff and erosion increase when land is sub-

jected to exploitative land use practices. They have also disclosed that soil betterment is accompanied by decreased surface runoff.

Among these studies, for instance, is a six-year record of rainfall and runoff in Missouri (6) which showed that 11.5 percent of total rainfall ran off a sloping surface protected by a grass covered soil while 49 percent was lost from bare soil. Another, in Mississippi (15), reveals that at the time of the disastrous flood of the Yazoo River in 1931-32, 62 percent of the 27 inches of rain that fell ran off from cultivated fields, 54 percent from abandoned fields, and 0.5 percent from an undisturbed forest. In southwestern Idaho, 0.4 percent of the water applied to wheatgrass on a range in good condition ran off while 60.8 percent ran off from a deteriorated area covered with annual weeds (3).

A very recent study in California (18) has shown that of an annual precipitation of 60.1 inches, on an area well protected by woodland-chaparral, 42.5 inches percolated through the soil and below the root zone. Here there was no surface runoff. From an adjacent similar area denuded of its cover, 23.6 inches of the rainfall went through the soil while 23.8 inches became surface runoff. The following year, when only 24.6 inches of rainfall was recorded, 8.3 inches percolated through the protected soil to replenish ground water and none ran off. On the denuded area, 6.5 inches went through the unprotected soil while 3.2 inches ran off. In both years, more water was available for ground water recharge on the protected sites than on the unprotected sites.

These are but a few of many examples which show increase in surface runoff with removal of protective cover. It makes but little difference whether the cover is removed and the soil damaged by harvesting a grain or cotton crop, or by livestock grazing, destructive logging, or fire. Results are the same. Water runs off the soil instead of through it. That water which runs off the land does not replenish ground water supplies.

The question of why this happens has also received attention. Lowdermilk (14) was the first to point out that surface runoff is greater from bare soil because a fine-textured, relatively impermeable layer was formed at its surface by the filtering of suspended particles from the percolating muddy water. Ellison (7) has enlarged on this by describing the effect of rainfall impact on puddling and sealing the surface soil. Duley (5) in a most remarkable series of photographs has shown how the soil surface is sealed and compacted by this action.

Removal of protective cover in areas where freezing occurs causes a concrete type of frost to develop in the soil. This is practically impermeable to water (13). By contrast, in areas well protected by vegetation, frost is largely absent or has a honeycomb structure which does not materially interfere with the movement of water into and through the soil. The occurrence of frost in each case seems to be correlated with amounts of soil organic matter, the lesser amounts under the unprotected areas being associated with the occurrence of the concrete frost.

The depth to which frost penetrates and its persistence are both greater in unprotected soils. As water cannot move into soils possessing a concrete type of frost, of necessity it must run across the surface. Again, this represents a loss to ground water increment stemming from land use practices. It is serious because soil frost stimulates surface runoff at the time of snow melt, a most important period in ground water replenishment.

Gully cutting lowers the water table. This is an often overlooked aspect of the effect of erosion on ground water supply. Commonly, areas possessing a water table close to or at the soil surface, are reclaimed for higher use by cutting channels to drain away the excess water. By so doing they lower the water table. The same principle operates whenever gullies cut down into the saturated zone—the water in the ground reservoir is lowered to the depth of the cut.

Such lowering of the water table is particularly noticeable in areas where snow-melt is the principle source of recharge. Here the spring rise of the water table from snow-melt is limited to the depth of the gullies, the deeper gullies functioning as ephemeral streams until snow has disappeared. It is also noticeable in extensive areas throughout the West where critical moisture conditions often exist. Conditions in the lower Colorado River Basin, for instance, have been recently described as follows: "*Deep gullies are trenching many valleys and draining the ground-water level below the reach of plant roots, making valueless large tracts that formerly produced excellent forage crops, and producing vast amounts of silt that became a troublesome problem to reservoirs, irrigation canals, and farms.*" (23).

As surface runoff increases under destructive land use practices, the ground water increment from rainfall is reduced. Those land use practices which protect the soil will, by holding surface runoff to a minimum, make available for ground water recharge a maximum supply of water at maximum rates. Again, there is evidence. Stallings' (19) review of studies on the effect of crop residue on reducing surface runoff and erosion gives ample proof. Bennett (2) shows that crop rotation as opposed to continuous cropping reduces runoff. He states that the best rotation is one that provides for a reduction of the area devoted to clean-tilled crops and keeps a dense cover of protective vegetation or stubble on the land during the season of intense rains and after

the harvest.

One of the classic illustrations of reducing surface runoff by increasing vegetal cover is provided by a study in central Utah (8) during which surface runoff was reduced 64 percent by protecting an overgrazed watershed so that density of its cover increased from 16 to 40 percent. Still another example, planting of black locust and osage orange in an abandoned field in northern Mississippi (15) reduced surface runoff from an estimated 40 percent of the precipitation to two percent.

Many other studies are in accord with this conclusion —protection of the soil reduces surface runoff. To reiterate, reduction of surface runoff is complemented with an increase of water moving into the soil, and therefore an opportunity for increasing ground water recharge. Under good land use, water tables can thus be replenished at their maximum rate.

The experience at Silver City, New Mexico provides an example of the effect of surface runoff on ground water supplies (25). *The 25 square-mile watershed, which provided the city's water supply, had long been overgrazed and misused. Floods resulting from increased surface runoff tore a great gully through the center of town. The rainfall, that at one time would have entered the soil and recharged ground water supplies, ran off the soil surface. Wells failed as ground water levels dropped. In 1925 the wells could barely supply 75,000 gallons of water a day. Then a watershed improvement program was started. Grazing was stopped, vegetation was protected, and minor engineering works were installed. As a result, surface runoff was translated into ground water recharge. Now it is possible to draw 200,000 gallons per day from the wells without depletion. Many other examples of this kind can be cited as one of the often reported results of soil conservation practice is increase in water supplies from wells.*

In a very real sense, soil conservation practices have the same effect as recharging the ground reservoir by water spreading. They facilitate the entrance of water into the soil. One of the main objectives of all soil conservation practices—strip cropping, contour plowing, winter cover crops, terracing, gully plugs, and tree planting—is to get precipitation into the ground. Water spreading, with the same objective, differs only by using diverted streamflow as the source of supply.

Water spreading is best achieved on those areas protected by natural cover (16). Tests at the Wasatch Front Research Center show that surplus flood flows from rapid spring snow melt can be spread on litter-covered soils of dense oakbrush stands for replenishment of underground storage. Rates up to 3-acre feet per acre of spreading area per day have been used without erosion and without diminution of the daily rate.

Soil Water Storage and Ground Water

Land use practices also affect the water storage capacity of the soil. This is due to the effect of the practices on evapotranspiration rates and on the depth of the rooting system. Although the capacity of the soil for storing water does affect the amount that reaches the ground water reservoir, the limiting factor is still the condition of the soil surface and the porosity of the soil mass. Obviously storage capacity can be utilized only if water can move into it.

Before citing evidence of the effect of land use practices on soil storage capacity, an understanding of certain fundamentals is necessary. First, is the portion of the soil mantle with which we are concerned. From the standpoint of watershed management this portion is the depth to which the mantle is occupied or can be occupied by plant roots. This depth is the zone in which both the storage capacity for water and its rate of movement is affected by land use practices, thus it is also the zone through which ground water recharge is affected.

The second, concerns the two types of water storage in the soil. One of these is the water held in storage by capillary attraction within the spaces between soil particles. The other is the free water stored or held in the soil only for the time necessary for it to pass through the soil and into ground water storage. Of utmost importance is the fact that capillary water storage in the soil must be satisfied before any free water can move into the underground reservoir.

The amount of recharge from any one rainfall will depend on the amount of water present in the soil at the time. If the soil is so wet that the capillary storage space is filled, there will be greater opportunity for the water that enters the soil to move downward into the ground water reservoir. If the soil is dry, the water that enters the soil will first go into capillary storage until it is filled; thereafter, any additional supply passing into the soil will be available for recharge. As evaporation and transpiration remove water from the soil, they affect the storage opportunity; as watershed practices affect evaporation and transpiration, they also must influence the storage opportunity and, of course, the ground water recharge.

The third, the shallower the root system the less is the storage capacity. The shallower the roots, the smaller is the amount of water that will be taken from the soil. The smaller the amount of water removed, the less will be needed to replace it. Substitution of shallow for deep rooted vegetation reduces the amount of water needed for satisfying soil storage requirements and increases the amount available for ground water recharge.

Both changes in evapotranspiration and soil water storage are reversible. By increasing transpiration an

increase of vegetal density will increase the storage capacity and decrease the amount of precipitation available for ground water recharge. An increase in depth of the rooting system will have a similar effect.

Recent research has proven the soundness of the above and provided an insight into results of previous work. In a study of the effect of timber cutting in Colorado (1), both total and lower-water runoff were increased from the cut-over basin. The increase in total flow was due to the greater amount of water made available for streamflow because of reduced transpiration. More important, low-water runoff, supplied from ground water storage, was greater, showing that ground water supplies had increased. To increase these supplies required the passage of more of the precipitation into the ground water reservoir. This could occur only if the storage capacity of the soil was reduced—which it was—by reduction of transpiration losses.

Likewise, in a more recent study in western North Carolina (10), total runoff was found to increase after clear-cutting the watershed by approximately the amount of water used by the trees. Both this study and the one in Colorado demonstrate that land use practices have a very definite effect on ground-water recharge and supplies. Further, they indicate that since increases in streamflow and ground water supplies follow the harvesting of the timber crop, cutting which does not disturb the soil surface may be a means of increasing water supplies in similar areas.

Burning over a watershed also affects streamflow and ground water. Following burning of a chaparral-covered watershed in California, streamflow showed an annual increase of 1.55 inches or 29 percent the next six years (11). Most significant is that 52 percent of this increase occurred during the dry season during which streamflow is derived from ground water storage. In this case, quickly established vegetation protected the soil, permitting the infiltration and percolation necessary for recharge, while at the same time transpiration was reduced, increasing the amount of water available for recharge. Burning, however, cannot be recommended as a means of increasing recharge. In this study, even though regrowth was rapid, erosion that immediately followed the fire deposited sediment in the stream which caused considerable damage to orchards, railroads and highways adjacent to the watershed.

The effect of root depth on soil storage capacity is beginning to receive recognition. A recent study in Utah (4) corroborates the reasoning that shallow rooted species provide less storage capacity. It was found at the end of the growing season, 11 inches of storage capacity were available under aspen, and eight inches on a plot from which the aspen had been removed, leaving only herbaceous vegetation as cover. In this area, the soil and ground reservoir are recharged by snow-melt; thus it would take 3 inches less snow-melt to satisfy the storage capacity of the soil occupied by the herbaceous species. This amount would be available for ground water storage and streamflow. Significantly, it was found that the aspen roots on this area penetrated the soil to a depth of six feet or more, two or three feet deeper than those of the herbaceous species. Deeper penetration of the aspen subjected the soil to a greater transpiration drain, thus increasing the amount of water needed to satisfy storage. The shallower rooted species removed less water, therefor, less was needed to fill storage, and more was available for ground water recharge.

Streamflow and Well Records

Unfortunately, it is impossible to use the many records of streamflow or of ground water level behavior to show the effect of land use practices. Few records have the required accuracy and they fall far short of covering the period of major changes in land use. Only about 0.5 percent of all the several thousand gaging stations operated have records that started before 1900. Only 15 percent cover a period of 25 years or more, while 50 percent cover ten years or less. Ground water well records are even briefer. As major land use changes were accomplished before 1890, it is obvious that these records cannot reveal their effect.

More important than the effect of the past major land use changes on ground water supplies is the effect of current land use practices. Again, hydrologic records obtained by agencies responsible for measuring streamflow and ground water levels are of no aid. These records are obtained, in the main, for large watersheds whose land use pattern is already fixed. Changes that do occur which would affect ground water can be easily nullified by changes whose effect would be in the opposite direction. Only by application of land conservation measures over entire watersheds would ground water supplies be significantly affected. Current conservation programs have not as yet reached that degree of application.

On the other hand, research under controlled conditions has demonstrated that land use practices affect water supply. Though most of the attention has been given to measurements of erosion and surface runoff under various land use practices, the information provided allows certain interpretations as to effects on ground water. A very few experiments have been made in which the effect of certain practices on ground water can be judged from their effect on streamflow. Needed is more research which would directly reveal the magnitude of their effects on ground water recharge and supplies.

(*Continued on page* 196)

Soil Fertility: A Major Factor in Conservation

EMIL TRUOG

A high state of fertility in the soils being cropped, says Professor Truog, is needed to give strong aid to the conservation of our soils, and conservation in general. Six reasons why this is true are outlined in the article. High fertility guards against soil erosion, aids in the removal of water by plants harmlessly, promotes better infiltration, helps to increase the organic matter content in soils, lessens the need for growing intertilled crops on hillsides, encourages better land use, and increases crop yields.

EVERY DAY NATURE GIVES us the cue to the best method of erosion control. For example, at the Conservation Experiment Station (2) near La Crosse, Wisconsin, no measurable runoff or erosion has occurred since 1936 on a timbered tract of land with a slope of 26 per cent. During this time, the area has been protected from fire and grazing so that Nature could have full sway. Thus, if in a region like Southern Wisconsin, we visit areas of good soils where the native forest or grass vegetation has not been disturbed, we find that soil erosion is under perfect control without even the aid of man. This means that erosion is slower than the rate of soil formation. If it were not, these fertile soils could not have been formed. On many contiguous areas, where the native vegetation has been replaced by crops which occupy the land only a portion of the time or make only a sparse growth, erosion of all degrees of severity has taken place.

These observations teach us that in order to control erosion, we should imitate Nature as nearly as possible. That is, we should keep the land covered with vegetation in the form of regular and catch or cover crops as much of the time as at all feasible. However, we must recognize that the success of this kind of a program is dependent directly on a high state of soil fertility, so that the needed vigorous vegetative growth will be attained quickly.

High Fertility Produces Protective Cover

Many of us have noted how quickly fertile plowed land produces a protective cover of volunteer vegetation when planting of the regular crop is delayed. And, then, we have noted how quickly crops planted on fertile soils grow into the desired protective cover. Also, we have noted that on poor or depleted soils, both regular and catch crops are slow in getting started, and every year the land if sloping and not in sod suffers a heavy toll by erosion.

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Now, just why does a vegetative cover provide the best protection against erosion? There are several reasons: In the case of sheet erosion, that is, the gradual but insidious type of erosion that often removes soil over much of the surface of even gently sloping but often the best agricultural fields, the most important reason is that a vegetative cover absorbs much of the impact of falling rain drops. When these drops fall directly on the soil, their impact causes a stirring up and puddling of the surface soil. By this is meant that the soil granules at the surface are broken down into fine particles so that they either become suspended in the water to be eroded away, or they settle into the pores or openings of the soil which ordinarily allow infiltration, and thus produce a seal against absorption of water by the soil. Thus, shortly after the start of a heavy downpour, such as causes much of our erosion, the infiltration rate will be greatly retarded and runoff and erosion increased accordingly. Sands are for the most part not subject to puddling, and hence, do not suffer much in this manner from the direct impact of rain drops. Erosion of clay, silt, and sandy loams, however, is often greatly accelerated through the operation of these phenomena. The only way this can be prevented is by providing a shield or canopy of living vegetation or a mulch of plant residues.

A second manner in which vegetation reduces erosion is by retarding the velocity of the water as it runs off the land. On a theoretical basis, a reduction in the velocity of water to one-half lowers its capacity to loosen or lift soil material to one-fourth, and to carry material in suspension to one-thirty second of the original. The velocity of runoff can, of course, be reduced by obstructions, such as vegetation, and the greater the density of the vegetation the greater the reduction. Here again, soil fertility comes into play, because the higher the fertility, the more quickly will dense vegetation develop.

It is well known that the roots of vegetation help to hold soil in place against removal by wind and water. Here also, the more fertile the soil, the greater the development of roots and the more favorable their action in this connection.

From what has been said, it is apparent that a dense forest, protected from fire and grazing, should be an ideal protection against erosion. The canopy of living leaves above and mat of dead and rotting leaves below shield the soil perfectly from the impact and stirring-up effect of the rain drops. Furthermore, the mat of dead leaves and humus formed therefrom serve as an enormous sponge which absorbs vast quantities of water and delivers it gradually to the soil below which is kept in ideal condition for allowing a maximum rate of infiltration.

Our native prairie grasses, under which some of our best soils were formed, also provide well-nigh perfect protection against erosion. Here the dense growth of grass, alive or dead, shields the soil from the raindrop-impact, and when runoff occurs, the grass sheds the water like shingles on a roof. The roots, being very numerous and fibrous, bind the soil together, and on decaying form humus to a considerable depth, imparting the typical black color of our corn belt soils. The effect of these various factors is to produce a soil that resists erosion and absorbs water readily.

Of the general farm crops grown, the perennial pasture and hay plants are the most effective in controlling erosion in the manner just discussed. If depletion of fertility by removal of these crops is compensated for by adequate fertilization and liming, there is no reason why under good management the rate of erosion cannot be controlled so it will be no greater or even less than rate of soil formation. Under these conditions, the soil can be maintained indefinitely or even improved. One reason erosion is so well controlled in many cases under native conditions is that fertility is maintained at a high level. Here again, we must imitate Nature.

Vegetation Transpires Water Harmlessly

All vegetation absorbs enormous amounts of water from the soil and then allows it to escape in the form of vapor to the air through tiny holes, called stomata, in the leaves. This intake of water by the roots, movement to the leaves, and escape there is called the transpiration stream. It is as necessary in the life of plants as is the drinking and excretion of water or watery liquids by man.

To supply the transpiration stream for most of our crop plants grown under average conditions requires, as has been repeatedly demonstrated, from 350 to 700 pounds of water for each pound of dry plant tissue produced. Usually the requirement for corn is close to the lower figure, and for alfalfa, close to the higher one. Thus, for each pound of alfalfa hay produced, approximately 700 pounds of water are absorbed by the alfalfa roots from the soil and given off by the leaves in the form of water vapor. Another way of stating this is to say that the water transpired in the growth of one ton of alfalfa hay on an acre of land is equal to a six-inch layer of water over this acre. Thus, to produce a four-ton season's yield of alfalfa hay per acre requires the absorption by the soil of 24 inches of precipitation and its delivery to the roots of the alfalfa.

Although corn is more efficient in its use of water, it still requires enormous amounts. The transpiration stream in the case of corn amounts to approximately 150 barrels (31½ gals. per barrel) of water for each bushel of corn produced. In the production of 100 bushels on an acre, the amount of water transpired is equal to a layer about sixteen inches deep over this whole acre.

When precipitation is transpired in the manner indicated, its disposition causes not erosion, but rather produces food and clothing. Moreover, the greater the crop growth or yield, as may be promoted by high soil fertility, the greater the use of water in this manner, and depletion of water in the soil reservoir so as to renew capacity for further absorption and thus lessen runoff and erosion. It should be pointed out that increased removal of water by greater transpiration may not markedly reduce runoff and erosion caused by heavy downpours, because in these cases water comes much faster than it can be absorbed by soil producing general farm crops. However, in the case of moderate rains, the transpiration factor may be of considerable importance.

High Fertility Promotes Infiltration

Obviously, the first step to take in an attempt to control erosion by decreasing runoff is to develop such soil characteristics as are favorable for the intake of water. The favorable influence of a vegetative cover in this connection has already been discussed. Fortunately, the soil itself can be managed in such a manner that it will resist puddling and develop a more porous structure.

Under certain conditions, soils develop what is called a granular structure, that is, a structure in which the soil particles join and form granules or aggregates both larger and smaller than pinheads. One granule may be made up of hundreds and even thousands of smaller particles varying in size down to some so small that they cannot be seen with a powerful microscope. The smallest particles are called fine clay, and along with much of the organic matter of soils represent the so-called colloidal fraction of soils. It is this colloidal material which serves as a glue to hold the larger, although still relatively small, particles together in the form of the aggregates or granules.

In a sense, these granules act just like large soil grains in providing larger pores for the intake of water. We all know that the coarser the particles are in a pile

of sand or gravel, the larger will be the pores or open channels, and the more rapidly will water move through the pile. The rate that water will move through a soil is dependent much more on the size of the pores than on the total pore space. A sand, for example, is about one-third pore space, and a silt loam about one-half; yet we all know that water will move much faster through the former than the latter. The reason for this is that sands are composed mostly of large individual soil grains which give rise to large pores. The remedy in the case of silt loams, sandy loams, and clays is to provide the conditions which favor the formation and maintenance of granules or aggregates. This requires good management, and particularly, provision for maintaining an adequate supply of organic matter.

When a soil is saturated with water, the colloidal material or glue in it becomes so thin that it loses much of its sticky strength, just like any paste or glue when it is too thin. If a soil is worked or agitated while in this condition, these grandules break down. That is what happens when a pounding rain hits it directly, or land is plowed or otherwise worked when too wet.

Now, it so happens that the presence of soluble salts in a soil lessens the tendency of the colloidal material or glue to become thin and watery and thereby allow the breakdown of these granules. This accords with a well-known principle of colloid chemistry. In general, the more fertile the soil, the higher will be the concentration of these salts in the soil, and the greater will be the favorable action.

Under practical farm conditions, formation of soil granules can usually be promoted more by providing organic matter than by attempting to maintain the needed supply of soluble salts which are subject to leaching just when most needed. This again is Nature's method. How can the average farmer provide the needed organic matter? That is one of the most important soil management questions facing our farmers today. In the case of gardens and other small areas, it may be done by applying compost made from leaves and other organic waste materials. To follow this same procedure in the case of farming in general is not feasible for two reasons: First, the supply of raw materials for making the vast amounts of compost needed just does not exist; second, the labor costs involved are prohibitory under our present economy.

Fortunately, there is a procedure for supplying the needed organic matter which is both feasible and profitable. This procedure consists of growing the organic matter as a by-product of regular cropping right on the land where it is needed. It is not necessary to interrupt the annual harvesting of income producing crops. All that is needed is provision for an adequate supply of lime and mineral nutrients in the soil so that luxuriant crops of legumes, grasses and other crops may be grown.

Figure 1. Alfalfa and alfalfa-brome mixture provide both excellent forage and well-nigh perfect protection against erosion. Here is a field in North Central Wisconsin on Spencer silt loam, a heavy soil with tight subsoil, which after treatment with five tons of lime and about 1000 pounds of 0-10-30 fertilizer per acre produced in excess of four tons per acre of hay annually for three years straight after establishment. This yield is more than double average yield of hay in Wisconsin and most other states.

It is sometimes said that nitrogen spells organic matter. Since legumes when properly inoculated are able to utilize atmospheric nitrogen, it is apparent that a program designed to put organic matter into soils should usually include one or more legumse in the cropping scheme or rotation. Often an admixture of timothy or brome grass is grown with such legumes as alfalfa and clover. This provides a type of organic matter which persists longer than that from legumes alone, and in addition the more fibrous grass roots which completely permeate the soil tend to stabilize the grandules and clods against destruction by the impact of rain drops. A mixture of alfalfa and timothy or brome provides an ideal combination in climates to which these crops are adapted. The brome or timothy provides the advantages just indicated, and the tap roots of the alfalfa on decaying provide the channels needed for the deeper infiltration of the water.

The supply of nitrogen in the air which may be drawn upon by legumes is stupendous. If the nitrogen in the air over one acre of land were fixed in the form of ammonium nitrate or some other nitrogen fertilizer, it would have a commercial fertilizer value of more than five million dollars. To contemplate the potential value of this resource over a whole farm staggers one's imagination. It may not be an exaggeration to say that if farmers were to adopt the soil management practices which would make full practical use of this resource, it

Figure 2. Well fertilized corn following sod crop produces well and usually does not entail serious erosion on rather level or moderately sloping land. This field is in southwestern Wisconsin. Treatment per acre at left, 125 pounds of 2-12-6 in hill, yielding 76 bu. per acre; at right, 125 of 2-12-6 in hill and 800 pounds 8-8-8 plowed under, yielding 108 bu. per acre which is more than double state average. With these high yields, need of corn on land subject to serious erosion is lessened or eliminated.

would constitute the greatest single forward step ever taken in the soil management field.

In temperate climates, alfalfa and clover are the most efficient transformers of atmospheric nitrogen into protein forms that make up a very essential portion of the tissues of these plants. The fertilizer value of the atmospheric nitrogen fixed by an acre of alfalfa during one growing season ordinarily falls in the range of fifteen to twenty-five dollars.

When a soil is in a high state of mineral fertility, the annual yield of alfalfa hay with or without timothy or brome commonly reaches four tons per acre, and the annual yield of roots and residues left on the field may equal one ton or more, dry basis, per acre. Thus, when the hay is fed to livestock, and the manure produced therefrom is returned to the land, the total annual return of organic matter in the form of manure, roots, and residues may equal two to three tons per acre, dry basis. On the wet or natural basis, this would be close to ten tons. Under this system, a high income producing crop is harvested at the same time that large additions of organic matter are added to the soil.

In warmer climates, much organic matter can be supplied through the growing of winter cover crops of legumes of several kinds. All crops, of course, leave considerable amounts of organic matter in the soil in the form of roots and residues. In general, the weight of the roots and residues of crop plants is equal to about one-third the weight of the above-ground or harvested portion, and the larger the crop, the greater the weight of roots and residues added to the soil. High soil fertility thus makes it possible to build up the organic matter content of soils to a point where it will serve as a very potent factor in controlling erosion.

No Need of Intertilled Crops on Hillsides

It is the row or intertilled crops, particularly corn and cotton, that most often give rise to conditions which favor severe erosion. There are several reasons for this: First, these crops leave much of the soil surface bare during the growing season. As a result, the puddling effect from the impact of rain drops on the soil surface is severe until these crops reach the growth needed to provide a protective canopy. Then, because much of the soil surface remains bare, and runoff water tends to concentrate in channels left by cultivation, conditions are provided which greatly accelerate erosion.

Although contour tillage and strip cropping will greatly lessen erosion when sloping land is planted to intertilled crops, successful operation of these practices is limited to land of moderate slope, that is a slope of less than 12 per cent. Whenever possible, it is highly desirable that these crops be not grown on slopes subject to severe erosion.

How can the needed production of these crops be attained without growing them on land subject to severe erosion? The answer in many cases is to raise the yields of these crops through appropriate soil management practices so that the needed production can be obtained when grown only on land not subject to severe erosion. Fortunately, considerable areas of such land exist on many farms. In some regions, additional areas of excellent level corn and truck-crop land can be provided through drainage and irrigation. Also, in many cases, yields of corn and other intertilled crops on the more level land can easily be increased by 50 to 100 per cent though adequate use of lime and fertilizer, and provision for good soil management practices. It has been estimated (1) that the average crop yields of the top ten per cent of the best farmers in this country are about 70 per cent above the general average of all farmers of the country.

Prior to 1900, the average yield of corn in North Carolina was 11 to 14 bushels per acre (3). Improved varieties and cultural practices including heavier fertilization have raised the present average yield to 30 bushels, and a goal of 40 bushels has been set for 1955. A preliminary estimate has set the average yield of corn in Wisconsin for 1949 at 49 bushels per acre. Where soil fertility was high, yields of 100 bushels and even more have been quite common. In other states, similar advances have been made in recent years.

These data leave little question but what the needed production of intertilled crops can be obtained in most cases from land that is not subject to severe erosion if

this land is adequately fertilized, drained in some cases, and improved cultural practices are followed. The making of silage from grass and legumes in place of corn, a practice which is increasing, should also help in promoting a retreat of corn from the hillsides.

High Fertility Promotes General Conservation

A high state of fertility of land devoted to the production of the common farm crops will definitely release much land for forestry and wildlife refuge, and this in turn will promote water conservation, preserve and improve our natural outdoor scenery, and thus promote the development of our recreational facilities to the highest possible degree. It is well known that underground water supplies are dwindling because of excessive use and because under our present soil management and land use programs too much of our precipitation is allowed or caused to run off rather than infiltrate into the soil. A cover of forest or wildlife-refuge vegetation is ideal for promoting the infiltration of water. That is the method Nature used to build the paradise the white man found when he first traversed this country.

So far I have said nothing about increasing yields through irrigation in the humid regions. The possibilities here are so great that I hesitate to even venture an estimate. The primary requisite for irrigation is an adequate supply of good quality irrigation water. In the humid region, proper water conservation will give us the supply which is so limited in arid regions. It is well known that lack of water at certain critical periods of a crop's growth often limits yields more than any other factor. Just one or two applications of water in the humid regions of this country will often double and treble the yields. With this supplemental irrigation, yields of potatoes of 600 to 800 bushels per acre are becoming common, and corn yields of 200 bushels per acre are being attained. In this conection one should note that 800 bushels of potatoes will supply the calories needed by a person for a period of twelve years, and that with an acre yield of 800 bushels, 13 million acres, approximately the arable area of Wisconsin, would supply the calory needs of all the people in this country; similarly with an acre yield of corn of 200 bushels, the arable land of Iowa, approximately 25 million acres, would supply twice the calory needs of our people.

Figure 3. Field of oats in south central Wisconsin. Yield per acre at right, no fertilizer, 80 bu.; at left, 500 pounds 0-20-20 and 100 pounds ammonium nitrate per acre, 124 bu., about three times state average. Yield with 500 pounds of 0-20-20 only was 100 bu.

All this leads to the conclusion that the average yields of our common farm crops in many of the major producing areas of this country could be raised 25 to 100 per cent and even more above the present levels. If this were done, think of the vast areas of land that could be turned back to Nature, and what this would mean for conservation in general. In Wisconsin, for example, two-thirds of the land area should be in forest and other vegetation that promote wildlife and water conservation. Fortunately, this country has the lime, fertilizer, water supplies, and know-how to do the job. All that is needed is a coordinated effort of all interested people and agencies already making a vigorous but too often piecemeal effort in the required direction.

High Fertility Provides Needed Capital

Although progress in soil conservation in the United States has made more headway in the past fifteen to twenty years than during all previous time, this progress is still far too slow. What is the reason for this slowness? Quite probably, it is just the natural tendency of people in general to resist adoption of new practices that require some changes in method of operation and additional expenditures of labor and money, even though it is apparent that in time this adoption will be highly profitable. Such soil conservation practices as terracing, contouring, and strip cropping usually do not bring immediately tangible profit. That is one of the main reasons why their adoption meets resistance. How can this resistance be lessened or overcome? Possibly it can be done, at least partially, by emphasizing more than has been done in the past the need of weaving into a soil conservation program such soil fertilization and management practices as will give, immediately, substantial financial returns. What evidence have we that such returns are possible?

In recent experiments in North Carolina (3) on 49 fields, it was shown that with adequate fertilization and improved soil management practices the yield of corn was increased on the average from 28 bushels to 81 bushels per acre. Since the main cost in producing corn is labor, and since this cost is practically the same whether the yield be low or high, it is apparent that a high yield is the key to profitable corn production. This advantage has been presented in a striking manner in the case of the North Carolina results: It is shown that in growing the lower yield of corn the farmer's return for his labor was at a rate of 48 cents per hour, while in the case of the higher yield it was 156 cents.

Now, to produce these higher yields, it is generally necessary to fertilize rather heavily at the start because the fertility level in many cases has been allowed to drop rather markedly over the years. After the initial heavy application of fertilizer has been made to establish the new and higher desired fertility level, ordinary applications will suffice to maintain the new level, providing, of course, that good soil management practices are followed, such as growing legumes regularly in the rotation.

In Wisconsin, there are many soils which are now producing up to only about one-half of their capability because their fertility level is low, due either to exhaustive cropping, or such a condition prior to cropping. These soils are receiving some manure, lime, and fertilizer, but only what may be called a maintenance ration, and never enough at one time to raise them up to a satisfactory fertility level. To do this may require the application of four or five tons of lime and one-thousand pounds or more of fertilizer per acre. This may cost twenty-five to fifty dollars per acre, but the returns start to come immediately, that is, in the first crop.

Recent experiments in Wisconsin show (4) that heavy initial fertilization and liming of soils which are potentially good soils except for a low or moderate level of lime and fertility elements make it possible to get good yields immediately, that is, four tons of alfalfa hay, seventy-five bushels of corn, and small grain in like proportion. Thus, the cost of the heavy initial soil treatment is often fully paid for by the increased yield during the first year, and practically always during the second year. After the initial heavy treatment has been made, much lighter treatments regularly made in the rotation suffice to maintain the fertility at the desired high level.

Calculations made in connection with the Wisconsin experiments show that the actual costs of the increased yields produced under a high level of fertility over ordinary fertility with adequate lime are eight to twenty cents per bushel for corn and small grains, and two to three dollars per ton for mixed alfalfa hay. These figures do not include the cost of harvesting the crops. Since the costs of plowing, planting, and cultivating are the same whether the yield be low or high, these costs do not enter into the expense of producing the increase represented by the higher yields. The additional expense is solely the cost of the fertilizer treatment. This was calculated as follows:

For example, if the cost of the initial heavy dose of fertilizer amounted to thirty dollars per acre, this cost was set up as a capital investment. Thus if the land was originally capitalized at one hundred dollars per acre, it is now capitalized at one hundred thirty dollars. Since the interest per annum on thirty dollars at five per cent is one dollar and fifty cents, this amount must be included in the cost of producing the increased yields.

Then there is the increased cost of the upkeep, that is, the cost of maintaining this higher fertility level.

(Continued on page 194)

Recent Research Reviews

JAMES H. STALLINGS

Properties of Soil Which Influence Wind Erosion. I. The Governing Principle of Surface Roughness. *By W. S. Chepil; Soil Science, Vol. 69, No. 2, pp. 149-162. February 1950.*

This study was conducted for the purpose of gaining more adequate information on the generally recognized but little understood relationship between erodibility of soils and their physical structure. It was concluded that the amount of soil erodible by wind is limited by the critical height of and distance between the unerodible fractions that are exposed at the surface by the wind. Erosion ceases as soon as this critical stage is reached. The ratio of height of surface projections to the distance between projections after soil removal has ceased remains constant irrespective of the size and proportion of the nonerodible clods contained in the soil. The ratio varies with other factors, however, such as wind velocity and size, shape and apparent specific gravity of the erodible fractions. These factors, as a whole, add considerably to the complexity of the erosional phenomenon.

A Simple Volume-Weight Sampler and Procedure. *By* E. J. Dortignac; *Soil Sci., Vol. 69, No. 2, pp. 95-105. February 1950.*

A volume-weight sampler and procedure are described for determining porosity of soils. The instrument is simple and inexpensive and has been used successfully on both cultivated and mountain soils. The field procedure suggested for determining relative distribution of pore sizes is readily used in conjunction with artificial rain maker and irrigation experiments. It can also be used after natural precipitation has saturated the soil horizon to be sampled. This field method is simple and rapid for surface soils, but more time-consuming for deeper soil horizons. The laboratory work involves merely weighing and over-drying soil samples.

The Role of the Atmosphere in the Hydrologic Cycle. *By* G. S. Benton, R. T. Blackburn *and* V. O. Snead; *Trans. Amer. Geo. Union, Vol. 31, No. 1, pp. 61-73. February 1950.*

Present day understanding of the hydrologic cycle is limited by the fact that little data have been compiled concerning mass movements of water in the atmosphere. As a result, relationships between precipitation, evapotranspiration, and runoff have been obscured. The role of the atmosphere in the hydrologic cycle is discussed, and the relationship of the hydrologic cycle to the air mass cycle is clarified. Taking the Mississippi Watershed as an example, quantitative estimates are prepared of the percentage of precipitation occurring from, and of evapotranspiration occurring into, maritime and continental air masses. These estimates are based upon quantitative studies for selected stations within the watershed. Pilot balloon and radiosonde data are utilized to determine the total flux of moisture in maritime and in continental air into the Mississippi Watershed. From these data a complete balance of the hydrologic cycle for the Mississippi Watershed is prepared. The results of this investigation are then used in analyzing the various phases of the hydrologic cycle. It is shown that only a small percentage of the maritime moisture advected over the continents is ever precipitated; that in spite of this fact most precipitation occurs from maritime air and is derived directly from oceanic sources.

Soil Erosion By Rainstorms. *By* W. D. Ellison; *Science, Vol. 111. No. 1880, pp. 245-249. March 10, 1950.*

Falling raindrops and surface flow are both active erosive agents during periods of heavy rainstorms. During periods of heavy rainstorms, raindrop splashed materials fall into thin films of free water on the surface of the ground and are swept down slope instead of falling back on the surface of the ground to be resplashed. Surface flow erodes by scouring the soil surface after the free water concentrates into channels.

Splash erosion can be controlled by breaking the fall velocities of raindrops before they strike the ground. This can be accomplished by use of mulches of straw or leaves, crop residues, or with dense growths of vegetal covers on the ground. Scour erosion can be controlled by regulating the contentration and controlling the velocity of flowing water after it becomes channelized.

These two erosive agents acting separately or in unison cause four distinct types of erosion. They are gully erosion, sheet erosion, fertility erosion, and puddle erosion. Fertility erosion is the removal of the soil's fertility elements and destruction of the land's water holding capacity. It is more prevalent on sandy soils. Puddle erosion hardens and seals the surface of the land so that water does not enter freely. It occurs on silty and clay soils, or those soils which are composed mainly of the finer textured soil particles.

The Reviews by J. H. Stallings that follow are a regular feature in the Journal. It is hoped that the projects reviewed from time to time will be helpful to conservationists everywhere. Members of the Society are urged to indicate their interest in the kind of research work that should be reviewed.

An Analysis of Forage Utilization Methods and a Proposal for Utilization Surveys by Range Condition Classes. *By* R. R. HUMPHREY; *Jour. of Forestry, Vol. 47, No. 7, pp. 549-554. July 1949.*

The "range condition method" of making forage utilization surveys is presented and described. The method has been tested for each of the past four years on about 38,600 acres of rangeland in Central Washington. It has proved rapid, easy to learn and apply, and has provided practical information that has been used by the ranches in modifying their management practices. The method is not new in the sense of providing wholly new principles or techniques. It adopts and enlarges upon ideas included in other methods, notably the general reconnaissance method and the high-weight method. It goes farther than these, however, in adding some new ideas and in combining the whole into a single, easily applied field technique.

Watershed Condition and Flood Control. *By* HOWARD W. LULL; *Jour. of Forestry, Vol. 47, No. 1, pp. 45-48. January 1949.*

A method of computing the expected runoff from a flood-producing storm on the Ephrain Creek Watershed is described in detail. Control measures needed to prevent such floods are suggested.

Reseeding Research in the Intermountain Region. *By* GEORGE STEWART; *Jour. of Range Mgt., Vol. 3, No. 1, pp. 52-59. January 1950.*

There are four generalized planting zones (sagebrush, mountain brush, subalpine, and salt-desert shrub) in the Intermountain region in which reseeding research at various levels has so far been done. Research is most advanced in the sagebrush zone. Species suitability is being tested at four sites in Ephraim Canyon, Utah, comparable in elevation to the four zones. Crested wheatgrass does better in the sagebrush zone than any other species of grass. At the higher sites, intermediate and stiffhair wheatgrasses and smooth brome outrank all other species.

Sagebrush can be eradicted most effectively by burning. Mechanical methods vary in effectiveness, with the wheatland plow (one-way disk), the offset disk, and the brushland plow all giving a 75 per cent kill or better. Moldboard and wheatland type plows are highly efficient mechanical means of reducing competition from wheatgrass; early summer burning is also particularly effective. Drilling of seed is generally more successful than broadcasting. In the Valleys and sagebrush foothills, a seeding rate of 6 to 8 pounds of crested wheatgrass to the acre is considered best. Seeding rates for adapted species of 12 to 15 pounds are best in the mountainous zones. The most favorable average time of seeding at the lower elevations has been during October.

Influence of Some Watershed Variables on a Major Flood. *By* H. W. ANDERSON *and* H. K. TROBITZ; *Jour. of Forestry; Vol. 47, No. 5, pp. 347-358. May 1949.*

Peak discharge and sediment deposition from watersheds during a major flood were found to be quantitatively related to forest cover density and other watershed characteristics. Forest fires as a principle cause of cover differences had an important effect in increasing peak disharges and erosion during a major flood. The independent effects of some watershed variables on peak discharges and sediment deposition were isolated in quantitative terms by means of multiple regression analysis.

Results of Thinning Experiment in Ponderosa Pine Pole Stands in Central Arizona. *By* HERMAN KRAUCH; *Jour. of Forestry, Vol. 47, No. 6, pp. 466-469. June 1949.*

Results of a twenty-year study in Ponderosa pine suggest that thinning may shorten the timber rotation by as much as thirty years.

Stabilization of Midwestern Grassland. *By* J. E. WEAVER; *Ecological Monographs 20(3): 251-270. July 1950.*

This is another chapter of the growing ecological classic—the chronicle of the Great Drought of the thirties in the prairies of Nebraska and Kansas by J. E. Weaver and his associates. This installment reports the progress of a decade of recovery by native grasslands after the drought. Many of the changes, notably the widespread extensions of western wheatgrass, have persisted. This and the preceding reports cited in the references, are "must" reading for conservationists who work with mid-continental native grasslands.

Causes of Succession on Old Fields of the Piedmont, North Carolina. *By* CATHERINE KEEVER. *Ecological Monographs 20(3): 229-250. July, 1950.*

The timing of events, such as seed maturity, in the life cycles of the principal dominant species is a major influence in the succession of plants on abandoned fields. The author has re-examined with considerable thoroughness the oft-suggested, and generally discarded, idea that certain plants excrete substances into the soil that stimulate or retard the growth of other plants, thereby causing the changes recognized as plant succession. She reports:

"There was no evidence from this investigation that toxic substances produced by one living plant influence other plants in such a way as to change the trend of succession. The rate of decay of different kinds of organic matter and the influence of that rate of decay upon the available minerals in the soil does affect the growth of plants and trend of succession."

—BEN OSBORN, *San Angelo, Texas*

FIELD NOTES AND COMMENTS

Conservation Irrigation Guide Developed for Charleston Area

Scientific information on irrigation gathered by Soil Conservation Service technicians in Charleston, Berkeley, and Georgetown Soil Conservation Districts in South Carolina has been brought together into a "*Conservation Irrigation Guide*" for use of technicians working with truck growers and other irrigators in these districts.

Local and Southeastern regional engineers who prepared the guide point out that although they expect to make continued refinements in conservation methods, the new guide brings up-to-date all the scientific information the Service has been able to gather from experiment stations, from farmers, and from soil permeability studies.

The guide, designed for use of Service technicians and other agencies, attempts to answer such questions as: 1. How deep should the soil be moistened for each crop? 2. How much water should be applied at each irrigation? 3. How often should crops be irrigated? 4. How fast can the water be applied? and 5. how long will one application take?

The guide points out that conservation irrigation simply means applying the needed amounts of irrigation water without waste or damage to the land, and maintaining soil fertility. Each soil must be irrigated according to its ability to take and hold water and each crop according to its needs and its root zone.

As specific examples of the need for exact information such as has been secured by permeability studies on local soils, the guide explains that Edisto sandy loam will take water at the rate of one inch an hour, but will hold only eight-tenths of an inch of water for each foot of depth; Bayboro loam, on the other hand, will take in water at the rate of only one-fifth of an inch an hour, but will hold two inches per foot of depth.

Information of this type is taking the guesswork out of irrigation operations in the truck growing areas of the Charleston section.

—Barrington King, *Spartanburg, S. C.*

Soil Permeability in Relation to Erosion Control Problems

The study of soil permeability, which has provided valuable information in relation to drainage problems, seems to offer even greater opportunities in the problems of erosion control.

Initial permeability studies of the Soil Conservation Service were undertaken because of the need of this information in soil conservation districts where drainage was a major problem. Results of these studies have enabled technicians to help farmers plan more efficient drainage systems on land suited for pasture or cropping. Is not this information just as essential in helping farmers develop plans for effective control of erosion?

Three processes of water movement, in addition to runoff, are involved in erosion control. These are (1) *infiltration,* (2) *percolation through the root zone, and* (3) *internal disposal, or the percolation of water through the rock crevices and seams from the root zone into the ground water profile below. This discussion will be confined to the second factor, the percolation of water through the effective root zone within the soil.*

As an indication of the importance of permeability in erosion control, we know that some soils have a percolation rate of 50 inches an hour and others a percolation rate of 0.01 inch an hour or less. Obviously, an erosion control system that would be adequate for the one would not be adequate for the other. This is an extreme example, but many wide variations exist in the percolation rates of soils as indicated in Table 1.

Table 1. *Percolation rates, in inches per hour, on six sites in North Carolina*

Site	Land Use	Field Identification Of Soil	Percolation Rate Inches Per Hour		
			Horizon A	Horizon B_1	Horizon B_2
24	Lespedeza	Davidson Clay Loam	24.00	0.5	0.05
28	Oats	Lloyd Clay Loam	1.74	0.05	0.02
29	Alfalfa (5 yrs.)	Lloyd Clay Loam	5.83	7.26	0.16
30	Small Grain	Lloyd Clay Loam	0.30	0.77	0.56
31	Truck Crops	Mayodan Sandy Loam	0.30	1.29	1.30
32	Young Pines	White Store Clay Loam	0.07	0.16	0.06

These figures indicate the wide differences in the rates at which water moves through the soil, the quantity of water that must be dealt with as runoff, and consequently, the need to adjust the erosion control system to the permeability of the soil. Clearly, the same system that is applied to Site No. 24, where the percolation rate in Horizon A is 24 inches an hour, should not be used on Site No. 32, where the percolation rate in Horizon A is 0.07 inches.

The two following tables indicate how greatly permeability can be changed by cropping methods. Results of percolation measurements in four determinations in consecutive years are shown for two Georgia sites, Nos. 1 and 2.

Table 2. *Influence on percolation rate of varying degrees of root development and decay on Georgia Site No. 1, planted to kudzu.*

Site	Date	Percolation Rate in Inches Per Hour Horizon A	Horizon B
1	January 1946	5.88	9.40
1A	April 1947	0.91	6.19
1B	March 1948	7.68	4.54
1C	March 1949	3.07	13.32

Table 3. *Influence on percolation rate of varying degrees of root development and decay on Georgia Site No. 2 planted to lespedeza serivea.*

Site	Date	Percolation Rate in Inches Per Hour Horizon A	Horizon B
2	January 1946	2.83	1.10
2A	April 1947	6.87	29.56
2B	Morch 1948	13.59	12.83
2C	March 1949	8.50	8.89

It might be pointed out also that the percolation rate of North Carolina Site No. 29, Horizon B_1, as shown in Table 1, was 7.26 inches per hour. A similar soil, North Carolina Site No. 30, Horizon B_1, not planted to a deep-rooted crop, had a percolation rate of 0.77 inches per hour.

The erodibility and permeability of soils are closely related. Under the same conditions, the rate of erosion can be expected to vary with varying soil permeabilities. For example, in our North Carolina soils, the highest percolation rate in any horizon of White Store soil is 0.16 inches per hour. On this soil any rain of greater intensity than this would produce runoff as soon as the surface soil was saturated. On Mayodan soil, B Horizon, with a percolation rate of 1.3 inches per hour, there would be no runoff until the rainfall intensity exceeded 1.3 inches per hour, provided the surface soil was kept open by cropping and tillage methods.

Our highly erodible soils, such as White Store, Craven, Orange, Vance, and Helena, invariably have subsoils of slow permeability. On the other hand, our least erodible soils have a moderately rapid or rapid permeability.

Sanding of terrace channels occurs where a loose sandy surface with rapid permeability is underlain by a subsoil with slow permeability. This means that when the surface soil becomes saturated and the subsoil cannot take the water as fast as it is received, more or less movement of soil into the terrace channels occurs.

During recent heavy rains in North Carolina, there has been much drowning of tobacco. This has occurred on soils where water was impounded by mechanical obstruction or on soils with very open sandy surface, overlying a less permeable subsoil which has resulted in the surface soil remaining saturated for some time.

This saturation occurs on slopes up to eight percent. The tobacco was drowned because the water could not escape below and was held in the surface soil long enough to asphyxiate the tobacco plants. I have never seen tobacco drown on soil with rapid permeability in the subsoil and substratum.

In the early days of the Soil Conservation Service, it was generally assumed that kudzu and sericea lespedeza would grow also anywhere. Now we know that they require well drained soils. They do not do well in North Carolina on soils with slow or very slow permeability.

It will take much time, effort, and study to explore this subject properly. But I am sure that the time will come when the information we are obtaining in soil permeability studies will affect our recommendations for erosion control by both vegetative and mechanical methods.

—W. W. STEVENS, *Raleigh, North Carolina.*

Snow Ridging Is an Important Moisture Conservation Practice

A new moisture conservation practice is being tried in north-central North Dakota, and experiences thus far hint that it may become important. The practice is snow ridging. That is, piling snow on cropland in ridges at right angles to the prevailing wind on well drained nearly level land, on the approximate contour on sloping land, and around pothole areas instead of through them.

Tests have not been under way long enough to draw conclusions, of course, but here are some things noted in 1949, the last year in which a year's experience has been completed (see accompanying table):

Systematic tests on two farms showed virtually no difference in the percent of soil moisture in the subsoil under ridged and unridged stubble land (land that went into the winter with the small grain stubble standing). Unridged land that had been fallowed the previous season had slightly less moisture in the subsoil than was beneath the stubble.

Topsoil on the ridged stubble land, however, had about a 20 percent higher moisture content than was in the topsoil on the unridged stubble land. There was an even greater difference between the topsoil moisture content of the ridged stubble land and the unridged fallow land.

It is to be noted that the spring of 1949 was one of the wettest on record, but there was a serious dry period later in the summer.

In August, when flax yield samples were taken, the stubble land on which snow had been ridged yielded three bushels an acre more on one farm and four bushels an acre more on the other farm than the unridged stubble

land yielded. The yield increase was worth 9 to 12 times the cost of ridging, which averages about $1 an acre.

About 25 percent of the annual moisture in the area where snow ridging is being tried comes as snow in winter. Much, if not most, of the snow is lost to the fields because of the severe winter winds. The winds pile the snow on roads and in coulees, pothole areas and tree groves, where it generally does more harm than good. At any event, the moisture is lost to the land on which the snow fell.

The first of this snow ridging was done during the winter of 1947-48, when a crawler-type tractor and bulldozer blade belonging to the Turtle Mountain soil conservation district was used. A half-dozen samples from each ridged and unridged area, taken the following summer, indicated that more exhaustive tests were warranted. Yield differences had a greater money value than the cost of ridging.

The present test setup was launched in the winter of 1948-49, with the farmers, soil conservation district, Soil Conservation Service and North Dakota experiment station cooperating. Fields selected are on the farms of Harold and Otto Bergman near Bottineau, North Dakota, cooperators with the soil conservation district. Snow ridging that winter was done early in January, 1949. In taking soil samples, topsoil was to a depth of 4 to 6 inches, and subsoil to a depth of 15 to 17 inches. Tests are still under way, the snow having been ridged the last winter and yield samples will be taken at harvest time this year.

In the meantime, more and more farmers in the area are taking up the practice, using their farm tractors and snow plows instead of hiring the work done with heavy equipment. More than 8,000 acres were ridged during the 1949-50 winter. Present recommendations are that the distance between ridges of snow should be between 20 and 30 feet.

Farmers are reporting a number of details concerning their experiences with snow ridging. In addition to helping prevent snow from drifting off their fields, they observe, the ridges catch snow drifted from nearby land. Again, each ridge functions as a dike in spring when the snow melts. Thus, the ridges hold the water on the land instead of letting it run off.

Harold Bergman reported that where ridging of the snow had been done around the pothole areas, less water ran into the depressions. Instead, he observed, it was held and soaked into the soil farther up slope.

A wildlife angle is injected, also. Most narrow shelterbelts in the area become so completely filled with drifted snow that the trees can offer little winter protection to game birds. Indications are that ridging fields on the windward side of such shelterbelts may reduce materially the amount of snow piled up in the trees. This may make the belts more effective for the winter protection of upland game.

Interest in snow ridging is expanding over a wider area in North Dakota, and the experiences of the farmers are being watched closely. Farmers who have tried it believe in it, and some now regard it as a normal farm operation.

—ELMER WORTHINGTON *and* WILLARD KUNKEL,
Bottineau, North Dakota

Legumes and Grasses Conserve Soil and Increase Digestible Nutrients

A five year rotation of corn, grain and three years of alfalfa is far superior to a three year rotation of corn, grain and one year of hay in conserving soil and producing digestible nutrients. Comparing yields from three and five year rotations for the period 1940-1946 at the LaCrosse, Wisconsin Soil Conservation Experiment Station show a yield of 67.1 bu. of corn, 92.0 bu. of oats and 2.5 tons of hay per acre when a three year rotation was followed and 82.6 bu. of corn, 94.0 bu. of oats and 3.4 tons of hay per acre when a five year rotation was followed.

Projecting these on to a typical 120 acre farm having 75 acres in cropland, 35 acres in permanent pasture, seven acres in protected woods and three acres in buildings and roads gives us the total digestible nutrients (TDN) and digestible protein (DP) shown in the following table.

Using TDN as the limiting factor, we find from the chart that we can feed approximately eight more cows on the same farm when using a five year rotation instead of a three.

Using local figures for crop yields, we developed a similar chart in Washington County, Stillwater, Minnesota for use in group meetings. We found that the charts have outstanding educational value in getting farmers to understand the value of legumes and grasses in the rotation.

Similar charts can be developed for any farming community using local yield. Rations to be fed should also be worked out for local conditions. Total milk produced and its value at local prices should be calculated. To illustrate, the 31 cows would produce 372,000 lbs. of milk at a value of $14,248, using local prices of $3.83 per hundred and 38 cows produced 456,000 lbs. valued at $17,465. This gives an additional gross income from milk of $3,217 in favor of using a five year rotation

which enabled the farmer to produce more milk. On the basis of linseed oil meal equivalent, there is an advantage of 21.6 tons for the five year rotation.

Water run-off and soil loss are also greatly reduced by using more grasses and legumes in the rotation. The water run-off at the LaCrosse, Wisconsin soil conservation Experiment Station when a three year rotation was followed was 7.1 inches and 5.5 inches when a five year rotation was followed. The soil losses were 54.8 and 47.04 tons per acre respectively when the three and five year rotation were used.

As stated before, presenting the material in the above form is very effective in creating more interest in erosion control through the use of more grasses and legumes in the rotation.

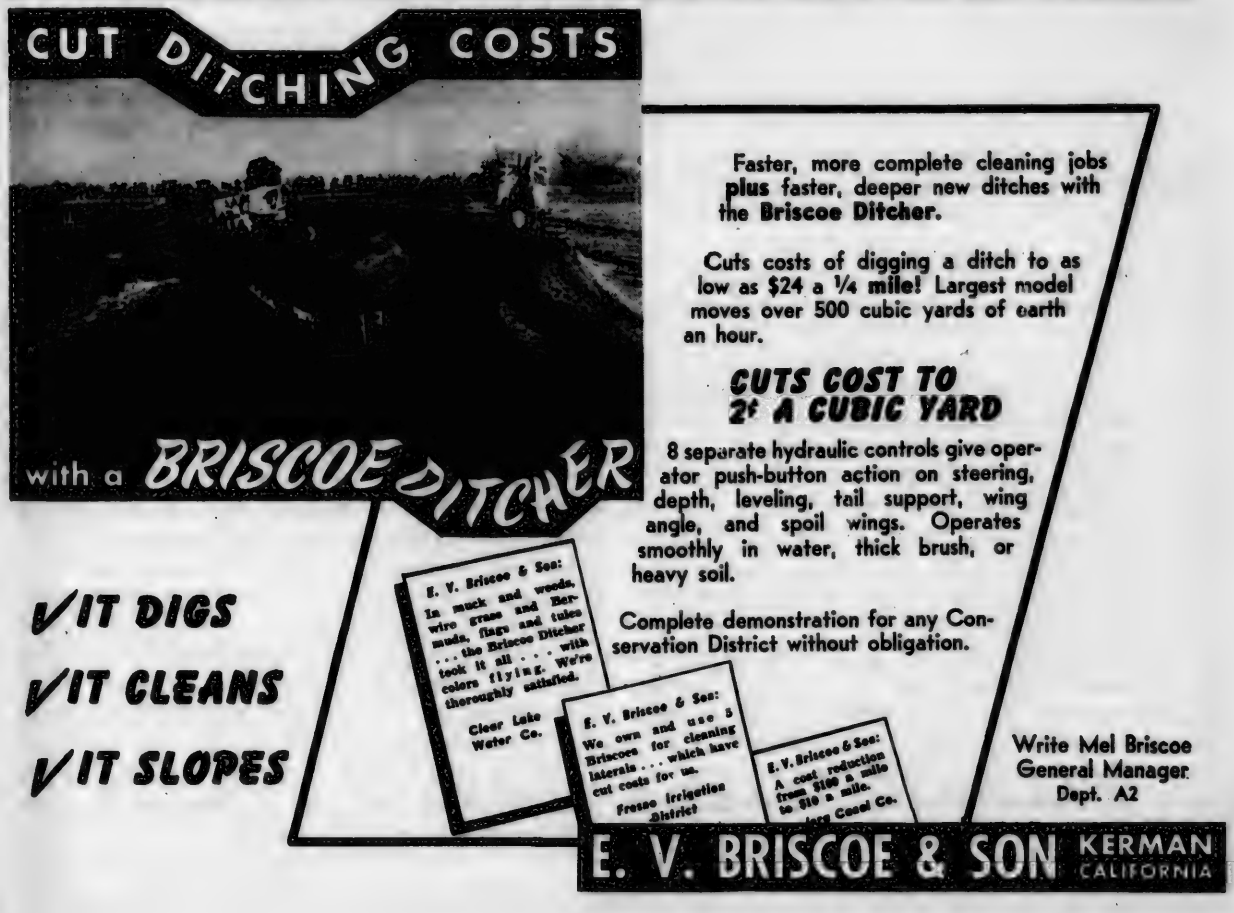
—FRANCIS L. PAULSON, *Stillwater, Minnesota.*

Production of DP and TDN on 75 Acres

Crop	Acres		Lbs. 3-yr. Rotation		Lbs. 5-yr. Rotation	
	3-year Rotation	5-year Rotation	[1]DP	TDN	DN	TDN
Corn	25	15	6,108	78,200	4,232	54,189
Oats	25	15	7,507	51,152	4,602	31,358
Alf.	25	45	13,000	64,250	31,824	157,284
Acreage Annual Yearly Production Per Acre			355	897	542	3,238
Total Yearly Production			26,615	193,602	40,658	242,831
Tons of Linseed Oil Meal to Produce the Same DP and TDN			40.9	128.5	62.5	161.2
[2]Milk Cows No.			36	31	55	39

[1]Feeding the dairy herd. Minn. Extension Bulletin No. 218.

[2]Farming with a three year rotation would produce enough digestible protein to feed 36 cows weighing 1,200 lbs. and producing an average of 40 lbs. of 3.5% milk daily for a ten month period or enough total digestible nutrients to feed 31 cows. The five year rotation would supply enough DP for 55 cows and TDN's enough for 39 for the same period.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BOOK REVIEWS

MUDDY WATER. *By* Mrs. Henrie Andrews. *Applied Economics, 280 Madison Ave., New York 16. 1949. 94 pages. 35 cents.*

Conservationists, school teachers, students and many others are finding the booklet "Muddy Water" helpful in developing Resource-Use programs throughout the Southeastern Region. *Muddy Water* was written by Mrs. Henrie Andrews Howell, a Mississippi public school teacher.

Mrs. Howell has combined fiction and fact into a very enjoyable account of the problems encountered in reclaiming a worn-out farm. The characters come alive and hold the interest of the reader throughout the story.

Readers will find much technical information about soil and water conservation woven into the story. Many of the problems encountered by this family are typical of those found in many parts of the South. It is a fascinating story of how people work together in developing and using our natural resources such as soil, water, forest, and wildlife. The basic principles of conservation are expressed in non-technical language, well illustrated by practical everyday farm problems.

Workshop directors are enthusiastic about the booklet. It gives the teachers an excellent illustration of how our natural resources should be used to improve the quality of living of all people.

J. W. Burdette, *Spartanburg, S. C.*

OUR PIPELINES TAKE TO COVER. *Booklet by the Natural Gas Pipeline Company of America, and the Texas-Illinois Natural Gas Pipeline Company, 20 North Wacker Drive, Chicago, Ill.*

This is the story of a natural gas pipeline company which over a period of years has developed a philosophy of soil and water conservation for stabilization of its high pressure large diameter lines.

The 16-page, 2-color publication is made up of newspaper and farm journal stories of what the Company is doing in soil and water conservation, how it works with soil conservation districts, local subdivisions of Government, farmer organizations, etc.

"Beneath A Carpet of Green" has become the by-word of the hundreds of employees of the two companies. Eighteen years of continuous service with not a single interruption of service because of unstable soil cover is the record of the Natural Gas Pipeline Company.

It is free from advertising and is well illustrated—a valuable booklet to industry. It is in the words of the every-day reporter of how an industrial organization puts soil and water conservation practices and farmer cooperation together for economic stability of the Company and "service with regularity, uninterrupted, and permanently to the housewife." It tells how the new 130 million dollar companion Company will follow in the footsteps of its older brother.

—Arthur W. Emerson, *Lincoln, Nebraska*

THE JOURNEY OF ALVAR NUNEZ CABEZA de VACA. *Translated from his own narrative by Fanny Bandelier. A. S. Barnes & Company. New York. 1905.*

Probably no other American pioneers survived such savage neglect and destitution as the shipwrecked Cabeza de Vaca and the Moor Esteben when they were lost in Texas and Mexico from 1528 to 1536. They were hungry and without clothing most of the time and never knew where they were. Cabeza de Vaca left America but Esteben remained to tell his pipe dreams about the golden cities of Cibola, which resulted in the disastrous fortune hunt but great exploration by Coronado from Mexico to Arizona, and on to Southern Kansas. In the book's introduction the author straightens out a significant misunderstanding about the geography of the men's travel along the United States and Mexican border. The statement reads as follows:

"This volume offers the original narrative of the first white man to cross North America. The remarkable journey of Alvar Nunez Cabeza de Vaca, Andres Dorantes, Alonso del Castillo Maldonado, and the Moor Estevanico, from Florida to Northwestern Mexico—(Sonora and Sinaloa), near the Pacific coast, antedates the expeditions of Coronado and De Soto. The journey of Cabeza de Vaca and his companions is an episode, important, but an incident brought about by a disastrous failure. This history describes the only—and comparatively meagre—results of the expedition undertaken by Pamfilo de Narvaez in 1527, and an outcome which had nothing more to do with Narvaez and his ill-conducted scheme. . . . A perusal of the narrative shows that the forlorn wanderers were not—as it has long been admitted—the "discoverers of New Mexico." They never saw, nor do they claim to have seen, any of the so-called "Pueblos." They only heard of them, in a more or less confused manner. On the other hand, more precise than their information on this point is what they said about the plains; their Indians; and it seems above all doubt that the first knowledge of the American Bison, or Buffalo, is due to their descriptions."

—B. W. Allred, *Fort Worth, Texas*

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Rural Life in the United States. *By* CARL C. TAYLOR AND OTHERS. *Alfred A. Knopf, New York. 1949. 549 pages.*

Eight authors combine their efforts to make this a comprehensive and authoritative survey of rural sociology in the United States.

The major theme of the book is based on what makes the farmers' way of living particularly American, now and in the past. Outstanding in the book are the Chapters based on American rural regions. The authors recognize and discuss in great detail seven major-type farm areas. Valuable, too, is the detailed and graphic analysis of rural population, institutions, occupations and standards of living.

Soil Fertility

(*Continued from page* 185)

The increased removal of fertility elements by higher yields must be paid for. However, since in livestock farming it is possible to return one-half of this removal in the form of manure, this upkeep cost is reduced or adjusted accordingly. In the Wisconsin experiments this adjusted upkeep cost was approximately one dollar and fifty cents per acre annually. This added to the interest charge brings the total annual cost per acre of the increased yields to three dollars per acre. In other words, it cost only three dollars more per acre annually to farm at the high level of fertility than at the lower or ordinary level. That is why farming at the higher level usually becomes very profitable.

The calculations just given involve the use of fertilizer on land already adequately limed. If liming is needed, its cost can be treated in the same manner as for fertilizer. Fortunately, the annual cost of bringing soils to an adequate lime level and maintaining them there is only about one dollar per acre in areas situated like Wisconsin.

There is, of course, the question of financing a program of the kind suggested. It requires some initial capital, but this can be kept to a minimum by proceeding on the basis of a gradual change-over, that is, by raising the fertility level of one or two fields each year, often the area to be seeded to alfalfa with small grain nurse crop, until the whole farm is transformed. The increased yield of the first harvest will start the payoff, so that the capital needed as the program proceeds will not increase excessively. Often after the second year, the value of the increased yields will equal or exceed the costs, so that by the time the whole farm is covered, the increased yields will have largely paid for the whole change-over.

Figure 4. Eight hundred bushels per acre of potatoes on well fertilized muck land in southeastern Wisconsin. Properly managed muck land is not subject to serious erosion and is well adapted to produce row crops which should retreat from the side hills.

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Land Use Practices

(*Continued from page* 179)

Conclusion

Land use practices affect ground water. Practices which leave the soil unprotected increase surface runoff and decrease the amount of water available for ground water recharge. Extensive erosion in this country attests to the result of these practices, and indicates the tremendous volume of surface runoff that has been required to move the soil. Not only has research repeatedly shown that surface runoff is increased by poor land use practices, it has also demonstrated that with wise use of the land, surface runoff becomes negligible.

Research has also shown that land use practices influence ground water through their effect on soil water storage. Soil water storage must be replenished before ground water recharge is possible. The amount of replenishment depends on storage space made available by evapotranspiration throughout the depth of the rooting system and as these are affected by land use practice, so is ground water recharge.

Finally, though the effect of land use practice cannot be determined with precision from the brief records of streamflow and wells, studies have shown that when watershed cover is removed, there is a change in both ground water supplies and streamflow.

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STATEMENT OF THE OWNERSHIP, MANAGEMENT, AND CIRCULATION REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1946 (39 U.S.C. 233)

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Soil Profile Characterization

(*Continued from page* 164)

1. Soil is considered as a complex, dynamic body whose present profile properties reflect use and treatment as well as original soil forming factors.
2. Soil profile characterization here starts with practical properties which directly influence use and treatment of the land.
3. Important practical properties are identified and expressed by the best available field and laboratory indices and measurements. The aim is to standardize observations and to measure whenever possible in order to place soil research and soil use on a sounder scientific basis directed toward more effective practical use of soil resources.
4. A simplified method of notation is offered in order to facilitate use of the system and to convey similar concepts to field and to laboratory scientists.
5. Calibrated indices for Puerto Rican conditions are suggested, together with illustrations of the application of the entire approach to generalized as well as to specific soil profile conditions.

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Bluestem on the Longhorn Trails

(*Continued from page* 157)

pounds of gain per acre over a four-year period.

Steers at Spur, Texas, Experiment station, gained 168.4 pounds per head over a four-year period and the per acre yield of beef has been about 35.6 pounds. Grass on this station was buffalograss, sideoats grama and tobosa.

Buffalograss is an aggressive invader in the Bluestem Belt where it has crowded in on the deeper soils as bluestems dwindled under grazing pressure. Buffalograss is an adaptive plant. It increases by seed and by its thrifty runners or stolons. It survives under heavy grazing by virtue of its mat forming growth habit. While it produces only about half as much forage as bluestem in the sub-humid prairies, it has a remarkable gift for survival. Very little is found in rocky or sandy land; hence, large areas of range land in the United States are not vulnerable to its invasion.

While it is generally an invader in the Bluestem Belt it is a bona fide member of the climax in the semi-arid Great Plains grassland. There too the grass has increased as the more palatable western wheatgrass and sideoats and blue grama have thinned out from grazing.

In the Bluestem Belt buffalograss sometimes is used as a base grass on small farm pastures where overseedings of rescuegrass, bur clover or other introduced plants often are made. Under these circumstances this combination makes satisfactory tame pasture.

All of the grasses discussed are good when used in their proper climate. Their palatability is acceptable; livestock make satisfactory gains on them. All are good soil conservation plants when grazed correctly. The mid and tall grasses yield the greatest animal gains in the sub-humid region where they are best adapted; they do not grow in semi-arid Great Plains except on sandy or well watered lowlands. The short grasses, buffalograss and blue grama originally were more prevalent on the hardland areas of the Southern Great Plains.

Civilization has infiltrated and killed out millions of acres of sod that once produced an ocean of waving grass in the great American heartland. But there are millions of acres of it left which is paying its way to stockmen who own it. All along the Eastern and part of the Western trail are bluestem grasses growing tall enough to brush away the flies from a steer's belly as he wades through, picking his living.

Journal of Soil and Water Conservation

Index to Volume 5

January 1950 to October 1950

ALLAN, PHILIP F.: Ecological Bases for Land Use Planning in Gulf Marshlands 57-62
ALLRED, B. W.: Bluestem on The Longhorn Trails 151
BEAR, FIRMAN E.: A Survey of the Minor Element Situation 11-12
Book Reviews
AMERICAN SOCIETY OF AGRONOMY AND THE NATIONAL FERTILIZER ASSOCIATION: Hunger Signs in Crops—*R. Y. Bailey* 81
ANDREWS, MRS. HENRIE: Muddy Water—*J. D. Burdette* 192
ASCH, JOHN: The Story of Plants—*B. W. Allred* 36
BANDELIER, FANNY: The Journey of Alvar Nunez Cabeza de Vaca—*B. W. Allred* 192
BEARD, ELIZABETH B., AND CHASE, WARREN: Outline of the Principles of Wildlife Management—*Douglas E. Wade* 39
BROWN, ROBERT L., MULLEN, LOWELL A., AND HAFENRICHTER, A. L.: Grasses and Legumes for Soil Conservation in the Pacific Northwest—*W. W. Austin* 127
CHASE, WARREN, AND BEARD, ELIZABETH B.: Outline of the Management of Fur Animals—*Douglas E. Wade* 39
CHASE, WARREN, AND BEARD, ELIZABETH B.: Outline of the Principles of Wildlife Management—*Douglas E. Wade* 39
COLE, A. P.: A New System of Agriculture—*H. J. Rath* 38
CLAWSON, MARION: The Western Range Livestock Industry—*B. W. Allred* 126
DAVISON, VERNE E.: Bobwhites on the Rise—*Logan J. Bennett* 81
DEGRAFF, HERRELL, AND HAYSTED, LADD: The Business of Farming—*Ben Osborn* 37
DEPARTMENT OF STATE: Proceedings of the Inter-American Conference on Conservation of Renewable Natural Resources—*Robert G. Snider* 129
DONAHUE, ROY L., AND EVANS, E. F.: Our South: Its Resources and Their Use—*Lawrence V. Compton* 81
EVANS, E. F., AND DONAHUE, ROY L.: Our South: Its Resources and Their Use—*Lawrence V. Compton* 81
HAFENRICHTER, A. L., MULLEN, LOWELL A., AND BROWN, ROBERT L.: Grasses and Legumes for Soil Conservation in the Pacific Northwest—*W. W. Austin* 127
HARROY, JEAN PAUL: Afrique: Terre Qui Meurt—*Edward H. Graham* 82
HAYSTEAD, LADD, AND DEGRAFF, HERRELL: The Business of Farming—*Ben Osborn* 37
IGNATIEFF, VLADIMIR: Efficient Use of Fertilizers—*Grover F. Brown* 83
LAPHAM, MACEY H.: Crisscross Trails—*Stanley W. Cosby* 34
LEOPOLD, ALDO: A Sand County Almanac—*William Vogt* 34
LORD, RUSSELL AND KATE: Forever the Land—*Channing Cope* 39
MULLEN, LOWELL A., BROWN, ROBERT L., AND HAFENRICHTER, A. L.: Grasses and Legumes for Soil Conservation in the Pacific Northwest—*W. W. Austin* 127
NATIONAL FERTILIZER ASSOCIATION AND AMERICAN SOCIETY OF AGRONOMY: Hunger Signs in Crops—*R. Y. Bailey* 81
OUR PIPELINES TAKE COVER—*Arthur W. Emerson* 192
PRESTON, JOHN F.: Farm Wood Crops—*A. L. Patrick* 126
PURI, A. N.: Soils: Their Physics and Chemistry—*J. G. Steele* 82
SAUNDERSON, MONT H.: Western Land and Water Use—*B. W. Allred* 130
TAYLOR, CARL C. and others: Rural Life in the United States 194
U. S. D. A.: Trees—The Yearbook of Agriculture—*Howard Mendenhall* 35
WENTWORTH, EDWARD NORRIS: America's Sheep Trails—*Ben Osborn* 80
WICKENDEN, LEONARD: Make Friends with Your Land—*Firman E. Bear* 37
WILDLIFE MANAGEMENT INSTITUTE: Transactions of the Fourteenth North American Wildlife Conference—*Philip F. Allan* 128
Conservation
Conservation—A Brief Appraisal. *Paul B. Sears* 55-56
Conservation as a Movement. *Carl C. Taylor* 103-105
Some European Soil Conservation Problems. *A. T. Semple* 63-70
CRIDDLE, WAYNE D.: Improving Farm Irrigation Practices 18-22
CROFT, A. R.: A. Water cost of Runoff Control 13-15
Drainage
Drainage in Conservation Farming. *T. W. Edminster, J. P. Walker and J. H. Lillard* 77-79
DWYER, CARROLL H.: A. Method of Computing Conservation Benefits of a Range Program 115-124
EDMINISTER, T. W., WALKER, J. P., AND LILLARD, J. H.: Drainage in Conservation Farming 77-79
Education
Conservation Education in the Public Schools. *Ellen Hartnett* 16-17
ELLISON, W. D.: Splash Erosion in Pictures 71-73
Erosion
Splash Erosion in Pictures, *W. D. Ellison* 71-73
Fertility
Soil Fertility: A Major Factor in Conservation—*Emil Truog* 180
Grass
Bluestem on the Longhorn Trails, *B. W. Allred* 151
GREENE, GEOFFREY E.: Land Use and Trout Streams 125-126
HANNAH, H. W.: Soil Conservation and the Rule of Law 106-110
HARTNETT, ELLEN: Conservation Education in the the Public Schools 16-17
Irrigation
Improving Farm Irrigation Practices. *Wayne D. Criddle* 18-22
LASSON, LEON, AND MUNNS, E. N.: Controlling Water on the Land 74-76
Law
Soil Conservation and the Rule of Law. *H. W. Hannah* 106-110
LILLARD, J. H., WALKER, J. R., AND EDMINISTER, T. W.: Drainage in Conservation Farming 77-79
LULL, H. W. AND MUNNS, E. N.: Effect of Land Use Practices on Ground Water 169
Minor Elements

A Survey of the Minor-Element Situation. *Firman E. Bear* 11-12
MUNNS, E. N., AND LASSEN, LEON: Controlling Water on the Land 74-76
MUNNS, E. N., AND LULL, H. W.: Effect of Land Use Practices on Ground Water 169
Professional
Ideals of a Professional Soil Conservationist. *Henry W. Schmitz* 27-31
Range Management
A Method of Computing Conservation Benefits of a Range Program. *Carroll H. Dwyer* 115-124
Research
The Contribution of Crop-Use Research. *Carl F. Speh* 7-10
Recent Research Reviews. *James H. Stallings* 32-33, 86-88, 132, and 186
ROSENE, WALTER, JR.: Quail Studies on a River Floodplain 111-114
SAMUELS, GEORGE AND SMITH, R. M.: A System of Soil Profile Characterizations 158
SCHMITZ, HENRY W.: Ideals of a Professional Soil Conservationist 27-31
SEARS, PAUL B.: Conservation—A Brief Appraisal 55-56
SEMPLE, A. T.: Some European Soil Conservation Problems 63-70
SMITH, R. M., AND SAMUELS, GEORGE: A System of Soil Profile Characterizations 158
Soil
A System of Soil Profile Characterizations—*R. M. Smith and George Samuels* 158
SPEH, CARL F.: The Contribution of Crop-Use Research 7-10
STALLINGS, JAMES H.: Recent Research Reviews 32-33, 86-88, 132, and 186
TAYLOR, CARL C.: Conservation as a Movement 103-105
TRUOG, EMIL: Soil Fertility: A Factor in Conservation 180
WALKER, J. P., EDMINISTER, T. W., AND LILLARD, J. H.: Drainage in Conservation Farming 77-79
Water
A Water Cost of Runoff Control. *A. R. Croft* 13-15
Controlling Water on the Land. *E. N. Munns and Leon Lassen* 74-76
Weeds—Water Robbers, *Robert B. Balcom* 165
Effect of Land Use Practices on Ground Water. *H. W. Lull and E. N. Munns* 169
Wildlife
Ecological Bases for Land Use Planning in Gulf Coast Marshlands. *Philip F. Allan* 57-62
Quail Studies on a River Floodplain. *Walter Rosene, Jr.* 111-114
Land Use and Trout Streams. *Geoffrey E. Greene* 125-126
Book Reviews—Volume 3, 1948
BALDWIN, MARK, AND OTHERS: Soil Conservation—An International Study 93
BLAIR, T. A.: Weather Elements—*David C. Winslow* 147
BUMP, GARDENER, AND OTHERS: The Ruffed Grouse—*C. R. Gutermuth* 91
EDMINSTER, FRANK C.: Fish Ponds for the Farm—*Lawrence V. Compton* 147
GORRIE, R. M.: Soil and Water Conservation in the Punjab—*M. W. Lowry* 187
GREENE, H.: Using Salty Lands—*Walter C. Gumbel* 144
GUSTAFSON, A. F.: Using and Managing Soils—*Firman E. Bear* 91
HARDING, T. SWANN: Two Blades of Grass—*Ben Osborn* 93
HOWARD, SIR ALBERT: The Soil and Health—*Melville H. Cohee* 45
JOHNSON, VANCE: Heaven's Tableland: The Dust Bowl Story—*Edward H. Graham* 92
OSBORN, FAIRFIELD: Our Plundered Planet—*Edward H. Graham* 142
PINCHOT, GIFFORD: Breaking New Ground—*Bernard Frank* 143
TANKSLEY, M. A.: Your Region's Resources—*David C. Winslow* 146
TANNEHILL, IVAN R.: Drought, Its Causes and Effects—*Ben Osborn* 45
UNRA: Ripe for Improvement. A Study of Marginal Land Farming in Greece—*William R. Van Dersal* 146
VOGT, WILLIAM: Road to Survival—*Luna B. Leopold* 186
Book Reviews—Volume 4, 1949
ALLRED, B. W., and CLEMENTS, EDITH S.: Dynamics of Vegetation—*W. R. Van Dersal* 173
BAVER, L. D.: Soil Physics—*Ben Osborn* 171
BEAUMONT, A. B.: Garden Soils, Their Use and Conservation—*W. W. Reitz* 173
CALEF, W. C.: Land Associations and Problems in the Uinta Country—*E. N. Munns* 174
CHASE, STUART: The Proper Study of Mankind 43
CHEW, A. P.: Plowshares into Swords—*Grover F. Brown* 43
CLEMENTS, EDITH S., and ALLRED, B. W.: Dynamics of Vegetation—*W. R. Van Dersal* 173
COPE, CHANNING: Front Porch Farmer—*Paul W. Chapman* 125
CROCKER, WILLIAM: Growth of Plants—*B. W. Allred* 171
DETURK, E. E.: Freedom from Want—*Firman E. Bear* 171
DOBIE, J. R., AND OTHERS: Propagation of Minnows and Other Species—*Lawrence V. Compton* 89
EDDY, SAMUEL, and SURBER, THADDEUS: Northern Fishes—*Lawrence V. Compton* 89
FOSTER, E. E.: Rainfall and Runoff—*Jack A. Griffin* 171
GILBERT, FRANK A.: Mineral Nutrition of Plants and Animals—*Firman E. Bear* 43
GLESINGER, EGON: The Coming Age of Wood—*Albert Arnst* 172
GRAHAM, EDWARD H.: Wildlife for America—*Wellington Brink* 125
KITTREDGE, JOSEPH: Forest Influences—*E. N. Munns* 88
OOSTING, HENRY J.: The Study of Plant Communities—*Ben Osborn* 87
PALMER, E. L.: Field Book of Natural History—*Frank C. Edminster* 125
PATON, ALAN: Cry, The Beloved Country—*Edward H. Graham* 88
SMITH, T. L.: Population Analysis 43
STODDARD, L. A.: Range Management—*B. W. Allred* 126
SURBER, THADDEUS, and EDDY, SAMUEL: Northern Fishes—*Lawrence V. Compton* 89
TRIPPENSEE, R. D.: Wildlife Management—*Wallace L. Anderson* 125
U.S.D.A.: Grass, The Yearbook of Agriculture—*Ben Osborn* 42

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